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WIND VELOCITY PROFILES MEASURED
BY THE SMOKE-TRAIL METHOD
AT THE EASTERN TEST RANGE, 1964

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SUMMARY

Twenty-six detailed wind profiles measured by the smoke-trail technique at the Eastern Test Range during the first seven months of 1964 are presented as plots of west-to-east and south-to-north velocity components at height intervals of 25 meters. The overall altitude ranges of the profiles vary from about 2.6 to 19.1 km. The wind measurements, which were made under a variety of conditions, include velocities in excess of the 90- and 95-percent highest values for the Eastern Test Range. The report also includes a listing of the wind profiles, their maximum velocities and direction of the maximum velocities, measured by the smoke-trail method at the Eastern Test Range from 1962 to 1964.

INTRODUCTION

An understanding of the detailed short wavelength wind velocity as a function of altitude was needed for dynamic response and control studies of vertically launched missiles and space systems (ref. 1). The shorter wavelength wind measurements could not be obtained from conventional balloon measurements because of tracking errors, self-induced motions of the balloons, and the horizontal drift of the balloons during ascent.

To provide the shorter wavelength wind measurements, the smoke-trail technique described in reference 2 was developed. A program for collecting data on winds aloft by means of the smoke-trail technique was conducted at Wallops Island, Va., and the Eastern Test Range, Cape Kennedy, Fla., from 1959 to 1969 and 1962 to 1964, respectively. Data collected at Wallops Island from 1959 to 1962 and 1963 to 1964 were published in references 3 and 4, respectively. Data collected at the Eastern Test Range during 1962 and 1963 were published in references 5 and 6, respectively.

The purpose of the present report is to present data collected during 1964 at Cape Kennedy and to summarize in somewhat more comprehensive form all of the data collected using the smoke-trail technique at that location.

MEASUREMENT TECHNIQUE

The method of measuring the details of the wind structure by means of smoke trails has been fully documented in reference 2, with later modifications to the method described in references 3 and 5. Only a brief review of the technique will be given here.

Basically, small rockets are used to eject a trail of chemical smoke over a near-vertical flight path. The smoke then serves as a sensitive tracer of the winds. Time-lapse photographs from modified aerial mapping cameras in operation at ground installations provide a basis for calculating wind velocities from the trail displacements over given time intervals. The triangulation needed to determine the position of the trail in space requires at least two ground installations, separated by sufficient distance to provide an adequate baseline. The camera network employed at Cape Kennedy is described in detail in reference 5. Briefly, it consisted of three camera stations. The False Cape station is located approximately 15 km NNW of the launch point; Williams Point is 23 km W, and the Patrick station is 26 km SSW of the launch point. The use of three stations provides a redundancy in case of cloud cover or camera failure at any one of the sites.

Figure 1 is a typical photograph of a smoke trail taken from one of the sites. The apparent tilt of objects in the photograph is due to camera tilt and the wide angle lens used, and is taken into account by the data reduction procedure.

RESULTS AND DISCUSSION

Plots of west-to-east and south-to-north components of wind velocity as a function of altitude are shown in figures 2 to 27. Wind-velocity values are computed for every 25-meter altitude increment and connected with straight-line segments, thus giving an appearance of a continuous curve. The data contained in these figures and references 5 and 6 are summarized in table I. The data presented in the table are shown in chronological order with Langley identification, date and time of launch, altitude range of each profile, and the maximum wind velocity and direction.

The wind-velocity data presented in figures 2 to 27 and references 5 and 6 are available on request from the NASA Langley Research Center on punched cards or in tabular form as a supplement to this report.¹ A sample tabulation illustrating the format of these data is shown in table II. In the tabulation, each profile is identified by a trail number, date and time of launch, time increment over which the data were taken, and camera and picture (frame) identification.

¹Requests should be directed to the Langley Research Center, Hampton, Va. 23365, and should include the author, title, and code number of this paper and specific profiles desired.

The various measures of the wind shear, or rate of change of wind velocity with height, are evaluated over a height interval of 25 meters and apply to the 25-meter height interval immediately below the reported height. These wind-shear values have been included in the tabulation because of numerous requests. However, the user should be aware of the large errors involved in computation of shears over an interval as small as 25 meters. For example, an rms velocity error of 1.0 m/sec would result in an rms shear error of 0.056 sec^{-1} . (Actual shear values as large as 0.056 sec^{-1} are seldom encountered.) Of course, the magnitude of the error decreases in proportion to an increasing altitude interval; thus, some users may find it desirable to average several of the reported values or to compute directly the shears over larger altitude intervals.

To provide pressure, temperature, and humidity data, radiosonde measurements were made at the Eastern Test Range within 6 hours of each of the smoke-trail launchings. The results of these data are available from the National Weather Records Center, Federal Building, Asheville, N.C. 28801.

As is shown in table I(c), the smoke-trail wind measurements reported herein were made in 1964 at the Eastern Test Range during the first seven months of the year. The overall altitude range of the wind-profile data varies from approximately 2.6 to 19.1 km; however, the length of individual profiles varies from 6 to 16.5 km. The characteristics of these profiles are similar to those profiles in references 5 and 6. The maximum scalar wind of 83.3 m/sec, measured at an altitude of 11.65 km (trail 383), exceeded the 95-percent highest wind (the value which will not be exceeded 95 percent of the time) for the month of February at 11.65 km; this value of 83.3 m/sec exceeds the 99-percent highest scalar wind for the year, based on data from reference 7. Five of the profiles exceeded the 90-percent value on a monthly basis.

Table III shows the maximum resultant velocity, the altitude at which it occurred, and the cumulative percentage frequency of occurrence of the velocity at its own altitude for the total sample of smoke-trail wind data taken at the Eastern Test Range. The total sample includes the wind-velocity data from references 5 and 6 and the data reported in the present paper. The maximum resultant velocity of the total sample is 88.7 m/sec (trail 340, ref. 6) which exceeds the 99-percent highest velocity for both the year and the month during which it occurred. This maximum velocity exceeds the maximum obtained in 1964 by 5.4 m/sec. In all months of the year, the median wind value (the wind velocity having a cumulative percentage frequency of 50) was exceeded at least once.

The detailed wind profiles of west-to-east and south-to-north wind velocity as a function of altitude (figs. 2 to 27) exhibit some interesting characteristics. For an example, the profiles shown in figures 5(a) and 10(a) exhibit rather large positive shears (wind component increasing with increasing altitude) at an altitude of 8 to 9 km. Similarly, the profile shown in figure 8(a) exhibits large negative shears on the spikes at an altitude

between about 12 to 17 km. However, most profiles have low-to-moderate peak values but exhibit considerable small-scale fluctuations.

A detailed assessment of accuracy is presented in appendix B of reference 5, which is directly applicable to the present results. Based on reference 5, the estimated overall rms vector errors of the wind profiles lie somewhere between 1/10 m/sec and about 1 m/sec, depending upon the particular camera pair used and the altitude range. For example, for the Williams Point—Patrick pair below 13 km, the rms vector error will be below 1/2 m/sec. On the other hand, the rms error for the False Cape—Williams Point pair above 13 km will be about 1 m/sec. Since the errors for the False Cape—Williams Point pair are not only larger but also increase more rapidly with altitude, the Williams Point—Patrick pair was used whenever possible.

Because the use of the smoke-trail technique is limited to periods of good visibility, a question arises as to whether the wind data gathered by this technique are biased or unrepresentative of the general distribution of winds at the location. Since one of the uses of these data is in the design of launch-vehicle systems where wind loads are an important design parameter, there is particular concern as to the possibility of smoke-trail winds being obtained preferentially in relatively low-wind situations, and thus not adequately sampling the high-wind cases which are of particular importance for vehicle design.

To examine this possibility, averages of winds measured by the smoke-trail technique were compared with averages of balloon-measured winds at altitudes of 11, 12, and 13 km, which are often critical altitudes for launch-vehicle loads. These comparisons are shown in figures 28 to 33. The balloon data shown are taken from reference 7, which tabulates mean values of actual radiosonde runs without regard for periods of missing data, and from reference 8, where missing radiosonde runs have been replaced by winds derived from other sources. The need for such supplementation and the techniques used are discussed in references 9, 10, and 11. While the smoke-trail averages for individual calendar months show considerable variability, as might be expected from the smaller size samples, they are not systematically lower or higher than the serially completed balloon wind averages from reference 8. In fact, they do not even show the degree of bias toward low winds exhibited by the unsupplemented balloon data of reference 7.

CONCLUDING REMARKS

Twenty-six detailed wind profiles measured by the smoke-trail technique at the Eastern Test Range during the first seven months of 1964 are presented. The wind-profile data presented include west-to-east and south-to-north velocity components at 25-meter altitude increments. The overall altitude range of the wind-profile data varies

from approximately 2.6 to 19.1 km; however, the length of individual profiles varies from 6 to 16.5 km. The characteristics of these profiles are generally similar to those published in NASA Technical Notes D-3289 and D-4880. Although most profiles have low-to-moderate peak values and exhibit many small-scale variations, the data include wind velocities in excess of the 90- and 95-percent highest value for the Eastern Test Range.

Langley Research Center,
National Aeronautics and Space Administration,
Hampton, Va., March 10, 1972.

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TABLE I.- LISTING OF EASTERN TEST RANGE WIND PROFILES

(a) Profiles for 1962 (ref. 5)

Trail identification	Date	EST	Altitude range, km	Maximum velocity, m/sec	Direction of maximum velocity, deg (a)	Altitude of maximum velocity, m
302	10/03/62	1530	3.8 to 15.4	16.4	254	13 850
303	8/08/62	1215	4.6 to 16.2	12.5	68	14 025
304	9/25/62	1528	3.3 to 11.4	^b 17.3	261	11 200
305	10/08/62	1300	4.2 to 16.4	18.1	321	10 350
306	10/10/62	1530	4.6 to 16.5	28.6	315	11 100
307	10/19/62	1453	4.8 to 13.0	^b 14.3	243	9 050
308	10/29/62	1513	5.1 to 13.2	^b 25.1	247	13 200
309	11/01/62	1502	3.9 to 15.8	25.5	235	13 025
310	11/05/62	1603	4.7 to 20.9	38.0	255	13 950
311	11/06/62	1549	4.2 to 16.2	55.4	263	13 975
312	11/13/62	1430	5.2 to 15.4	29.2	287	9 200
313	11/16/62	1523	3.7 to 17.8	34.4	273	14 200
314	12/04/62	1507	3.0 to 15.9	50.2	273	12 725
315	12/06/62	1620	5.0 to 14.2	^b 60.2	254	13 950
316	12/10/62	1230	4.2 to 16.2	74.9	233	11 925
317	12/11/62	1547	3.8 to 14.0	^b 46.8	250	13 775
318	12/13/62	1500	3.2 to 19.0	54.0	267	12 575
319	12/14/62	1436	2.3 to 17.8	54.1	282	12 875
320	12/17/62	1526	3.8 to 16.6	28.0	349	9 775
321	12/18/62	1203	3.2 to 14.4	31.6	330	9 525
322	12/19/62	1200	4.5 to 18.2	29.3	269	13 425
323	12/20/62	1447	3.7 to 16.0	25.9	284	11 200
324	12/21/62	1226	4.2 to 15.0	41.5	274	12 875
325	12/28/62	1307	3.6 to 21.4	46.8	269	13 775
368	11/16/62	1245	11.4 to 18.1	29.0	268	14 150

^aDirection from which wind is blowing, measured clockwise from true north.^bJet-stream maximum velocity may not have been measured.

TABLE I.- LISTING OF EASTERN TEST RANGE WIND PROFILES - Continued

(b) Profiles for 1963 (ref. 6)

Trail identification	Date	EST	Altitude range, km	Maximum velocity, m/sec	Direction of maximum velocity, deg (a)	Altitude of maximum velocity, m
326	1/03/63	1458	3.1 to 13.9	42.8	308	11 950
327	1/03/63	1600	3.3 to 11.7	b39.8	307	11 700
328	1/04/63	1500	3.0 to 14.8	44.9	292	12 225
330	1/09/63	1300	4.1 to 14.7	46.8	272	12 975
331	1/10/63	1430	2.8 to 20.6	50.4	256	10 975
332	1/11/63	1442	5.1 to 15.8	52.0	251	13 150
333	1/17/63	1617	3.7 to 15.2	53.0	275	12 875
334	1/18/63	1717	2.8 to 15.0	50.2	271	14 175
335	1/22/63	1446	2.9 to 14.9	52.3	281	13 425
336	1/28/63	1300	4.5 to 16.1	49.4	259	13 125
337	1/31/63	1500	5.6 to 15.0	38.7	287	14 375
338	2/07/63	1245	3.4 to 22.3	53.0	267	14 625
339	2/13/63	1315	4.2 to 15.8	70.2	252	10 800
340	2/20/63	1430	4.1 to 18.4	88.7	231	10 450
341	2/27/63	1430	5.0 to 13.9	b46.2	256	13 875
342	3/08/63	1420	4.3 to 20.5	51.2	256	13 900
343	3/11/63	1630	4.1 to 14.4	b32.9	277	14 375
344	3/12/63	1425	4.7 to 14.5	35.3	290	12 400
345	3/18/63	1430	3.3 to 14.7	40.6	306	12 000
346	3/21/63	1410	3.6 to 15.1	70.0	265	11 525
347	3/22/63	1330	3.8 to 16.1	60.7	259	11 450
348	3/28/63	1302	9.0 to 21.3	45.9	267	14 500
408	3/28/63	1510	11.1 to 19.2	46.0	260	14 175
349	4/02/63	1423	4.9 to 13.3	b30.0	14	13 350
350	4/03/63	1420	5.9 to 14.0	b27.6	17	11 500
351	4/05/63	1403	4.6 to 14.7	20.5	281	13 400
352	4/11/63	1535	3.7 to 14.6	39.7	325	10 450
353	4/12/63	1425	3.7 to 11.7	b46.5	280	11 650
354	4/15/63	1430	4.8 to 15.8	46.4	282	13 000
355	4/16/63	1430	4.7 to 21.5	29.6	293	14 250
356	4/17/63	1430	3.5 to 16.0	25.6	294	14 700
357	4/22/63	1430	4.1 to 12.5	b39.9	309	12 400
358	5/07/63	1530	6.5 to 15.5	30.4	300	12 625
359	5/08/63	1430	4.5 to 13.5	b27.8	320	13 325
360	5/14/63	1635	5.3 to 16.6	19.6	290	11 900
361	6/07/63	1400	3.4 to 13.3	23.5	203	12 725
362	6/19/63	1545	4.4 to 16.0	14.4	205	10 025
363	7/01/63	1300	2.2 to 16.7	17.6	126	14 200
364	7/17/63	1430	5.1 to 14.3	12.1	35	13 750
365	7/26/63	1430	5.4 to 19.9	13.4	85	18 225
366	7/31/63	1430	2.3 to 17.0	19.9	83	12 425
367	8/07/63	1430	2.3 to 19.4	16.0	161	12 925
369	9/30/63	1430	8.9 to 20.2	18.5	207	10 050
370	10/01/63	1512	8.0 to 20.3	21.7	228	11 075
371	10/09/63	1530	3.7 to 12.8	41.8	271	11 875
372	10/22/63	1417	7.5 to 15.9	19.8	344	11 300
374	10/30/63	1430	4.0 to 18.0	39.5	268	12 175
373	10/31/63	1530	4.4 to 18.6	26.3	275	14 825
375	11/06/63	1430	3.2 to 18.6	43.8	278	10 175
376	11/13/63	1511	3.6 to 20.2	75.5	251	11 475
377	11/15/63	1433	5.4 to 20.3	57.0	245	12 900
378	11/21/63	1430	3.9 to 19.4	42.0	331	12 850
379	12/05/63	1525	4.9 to 15.5	40.3	266	12 950
380	12/20/63	1230	5.0 to 16.4	68.7	277	11 475

^aDirection from which wind is blowing, measured clockwise from true north.^bJet-stream maximum velocity may not have been measured.

TABLE I.- LISTING OF EASTERN TEST RANGE WIND PROFILES – Concluded

(c) Profiles for 1964

Figure	Trail identification	Date	EST	Altitude range, km	Maximum velocity, m/sec	Direction of maximum velocity, deg (a)	Altitude of maximum velocity, m
2	381	1/22/64	1352	3.5 to 18.3	57.3	303	11 800
3	382	1/24/64	1400	3.6 to 17.7	51.8	277	14 100
4	383	2/19/64	1600	8.2 to 14.2	83.3	246	11 650
5	384	2/20/64	1330	4.7 to 19.0	74.6	252	10 975
6	385	2/26/64	1555	5.3 to 15.3	60.7	264	11 525
7	386	3/13/64	1330	4.2 to 16.6	48.6	281	13 450
8	387	3/18/64	1330	6.5 to 16.6	52.1	286	11 225
9	388	3/20/64	1505	4.9 to 14.8	55.6	268	13 300
10	389	3/31/64	1330	3.3 to 15.5	50.2	266	12 600
11	390	4/01/64	1330	4.7 to 14.5	56.1	312	10 875
12	391	4/03/64	1300	4.8 to 17.6	42.0	286	12 650
13	392	4/13/64	1445	5.6 to 18.7	49.7	280	13 925
14	393	4/22/64	1500	5.8 to 16.0	39.2	313	14 100
15	394	5/20/64	1330	5.2 to 17.3	42.6	272	13 100
16	395	5/21/64	1330	5.2 to 14.1	37.9	281	13 425
17	396	5/25/64	1505	3.9 to 18.3	25.4	321	14 125
18	397	5/27/64	1430	2.6 to 17.1	25.0	128	13 250
19	398	6/09/64	1400	8.0 to 16.5	23.1	311	14 825
20	399	6/10/64	1315	6.6 to 16.0	10.9	99	7 825
21	400	6/12/64	1400	5.0 to 17.3	25.6	51	13 025
22	401	6/15/64	1400	4.3 to 16.6	13.2	91	16 250
23	402	6/17/64	1400	7.3 to 14.6	8.4	31	13 125
24	403	7/06/64	1445	6.0 to 16.9	16.4	0	15 975
25	404	7/15/64	1320	5.0 to 15.9	14.9	344	12 975
26	405	7/28/64	1300	3.9 to 14.5	16.4	121	14 250
27	406	7/29/64	1300	2.6 to 19.1	16.8	133	13 775

^aDirection from which wind is blowing, measured clockwise from true north.

TABLE II.- SAMPLE TABULATION

CAPE WILLIAMS		SMOKE TRAIL NO. 383 LAUNCHED POINT NORTH PATRICK		2/19/64	1600 EST FRAMES	DELTA T 13 AND 25	60 SECS	
Z (METERS)	VX (MPS)	VY (MPS)	V	THETA (DEGREES)	SHEAR X (/SEC)	SHEAR Y (/SEC)	SHEAR V (/SEC)	SHEAR M (/SEC)
11200	75.5	30.4	81.39	248.06	.008	-.004	.009	.006
11225	75.7	30.3	81.54	248.19	.008	-.004	.009	.006
11250	75.8	30.2	81.62	248.32	.006	-.006	.008	.003
11275	75.9	29.9	81.59	248.47	.002	-.008	.009	.001
11300	75.9	29.8	81.59	248.56	.002	-.005	.005	0.000
11325	75.9	29.7	81.56	248.63	0.000	-.004	.004	.002
11350	76.0	29.7	81.56	248.67	.001	-.002	.002	0.000
11375	76.1	29.6	81.62	248.71	.003	-.001	.003	.002
11400	76.0	29.6	81.60	248.73	-.001	-.002	.002	.001
11425	76.1	29.6	81.63	248.71	.001	.002	.002	.001
11450	76.1	29.7	81.71	248.67	.002	.004	.004	.003
11475	76.1	29.9	81.80	248.57	.001	.006	.006	.003
11500	76.4	30.4	82.20	248.31	.009	.020	.022	.016
11525	76.7	31.0	82.71	248.00	.012	.024	.027	.021
11550	76.7	31.4	82.91	247.74	.002	.017	.017	.008
11575	76.6	31.9	82.99	247.40	-.004	.019	.020	.003
11600	75.8	32.3	82.42	246.91	-.032	.018	.027	.023
11625	76.1	32.9	82.89	246.59	.010	.024	.026	.018
11650	76.3	33.4	83.27	246.32	.008	.020	.022	.015
11675	74.6	34.6	82.19	245.13	-.068	.045	.081	.043
11700	73.1	30.6	79.29	247.26	-.057	-.157	.167	.116
11725	73.7	30.3	79.85	247.34	.022	.005	.023	.022
11750	74.2	30.8	80.32	247.47	.020	0.000	.020	.018
11775	74.7	30.5	80.64	247.80	.019	-.012	.022	.013
11800	74.9	30.1	80.70	248.09	.008	-.014	.017	.002
11825	75.0	29.9	80.70	248.29	.004	-.010	.011	0.000
11850	74.9	29.6	80.53	248.44	-.003	-.010	.011	.007
11875	74.9	29.5	80.54	248.49	.001	-.002	.003	0.000
11900	75.2	29.5	80.82	248.56	.012	.001	.012	.011
11925	75.4	29.4	80.94	248.70	.008	-.006	.010	.005
11950	75.5	29.9	80.89	249.04	.005	-.019	.019	.002
11975	75.8	28.7	80.99	249.28	.008	-.011	.014	.004
12000	76.0	28.4	81.16	249.49	.011	-.009	.014	.007
12025	76.1	27.9	81.00	249.88	.001	-.023	.023	.007
12050	76.2	26.2	80.55	251.00	.004	-.066	.066	.018
12075	76.6	25.7	80.82	251.59	.020	-.023	.030	.011
12100	76.7	25.2	80.74	251.83	.003	-.019	.019	.003
12125	76.9	24.9	80.85	252.05	.008	-.010	.013	.005
12150	77.0	24.6	80.82	252.29	.003	-.012	.013	.001

Z	altitude, meters
VX	west-to-east component of velocity, meters per second
VY	south-to-north component of velocity, meters per second
V	magnitude of resultant velocity, meters per second
Theta	direction from which wind is blowing, measured clockwise from true north, degrees
Shear X	$\delta VX / \delta Z$, per second
Shear Y	$\delta VY / \delta Z$, per second
Shear M	$ \delta V / \delta Z $, per second
Shear V	$\sqrt{\left(\frac{\delta VX}{\delta Z}\right)^2 + \left(\frac{\delta VY}{\delta Z}\right)^2}$, per second

TABLE III.- MONTHLY MAXIMUM WIND VELOCITIES

[1962 - 1964]

Month	Number of cases	Maximum measured wind			CPF (a)
		Trail	Maximum velocity, m/sec	Altitude, m	
Jan.	13	381	57.3	11 800	76.7
Feb.	7	340	^b 88.7	10 450	99.5
Mar.	12	346	70.0	11 525	91.2
Apr.	13	390	56.1	10 875	87.8
May	7	394	42.6	13 100	86.9
June	7	400	25.6	13 025	82.6
July	8	366	19.9	12 425	88.9
Aug.	2	367	16.0	12 925	76.9
Sept.	2	369	18.5	10 050	91.3
Oct.	10	371	41.8	11 875	90.5
Nov.	10	376	75.5	11 475	98.7
Dec.	14	316	74.9	11 925	98.8
Total . . . 105					

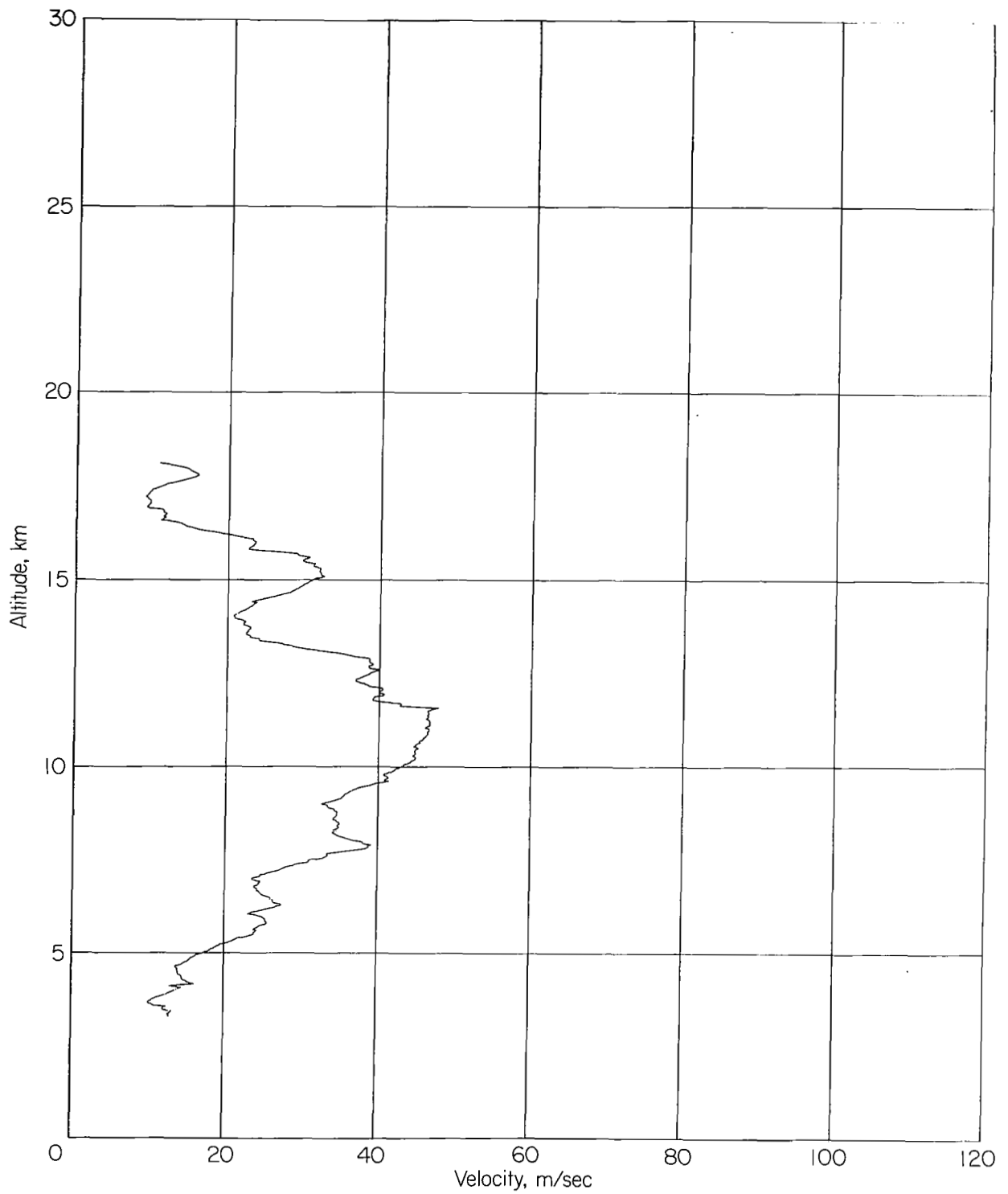
^aCumulative percentage frequency from reference 7.

^bMaximum wind measured for the total sample.



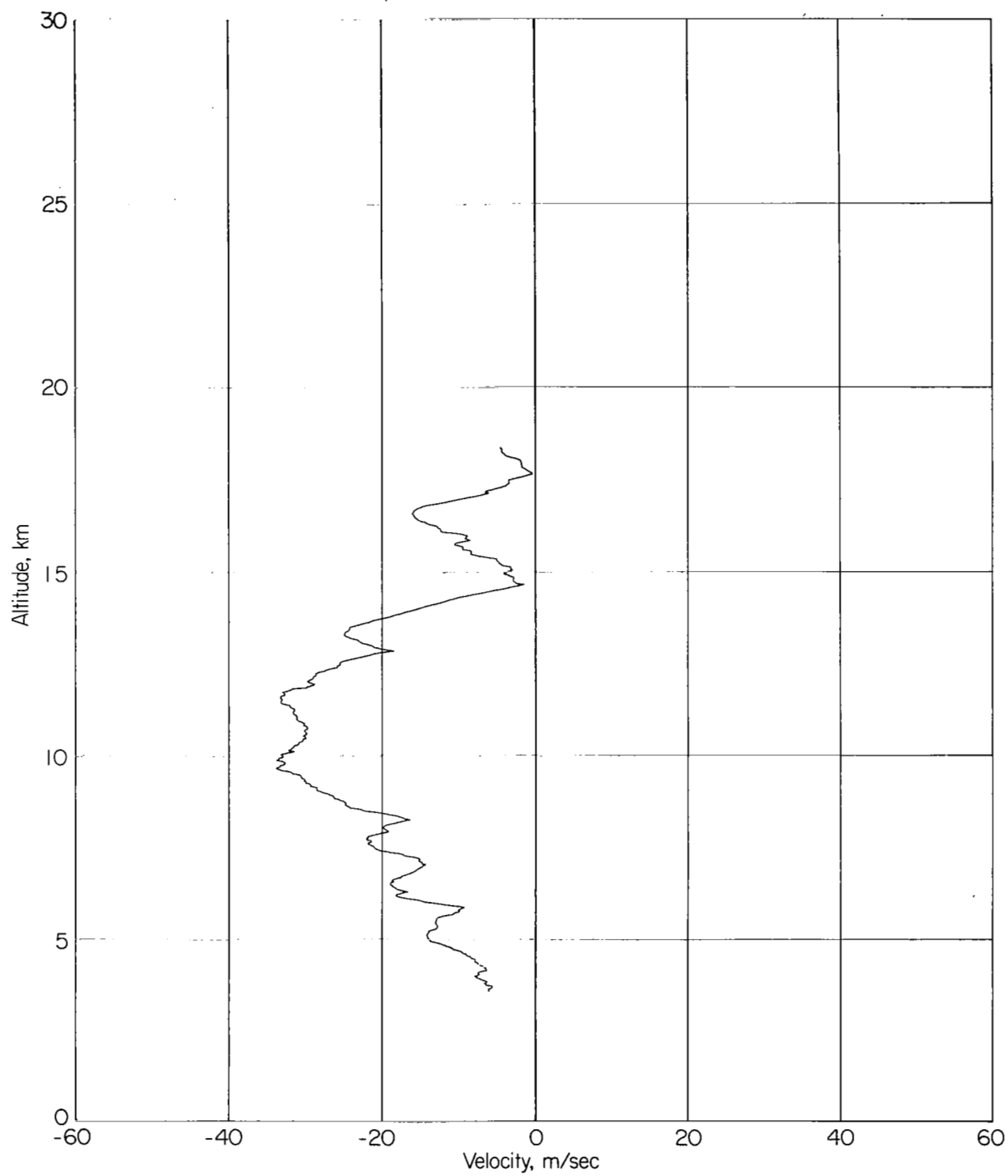
L-68-5681

Figure 1.- A smoke trail as photographed from one camera site at the Eastern Test Range.



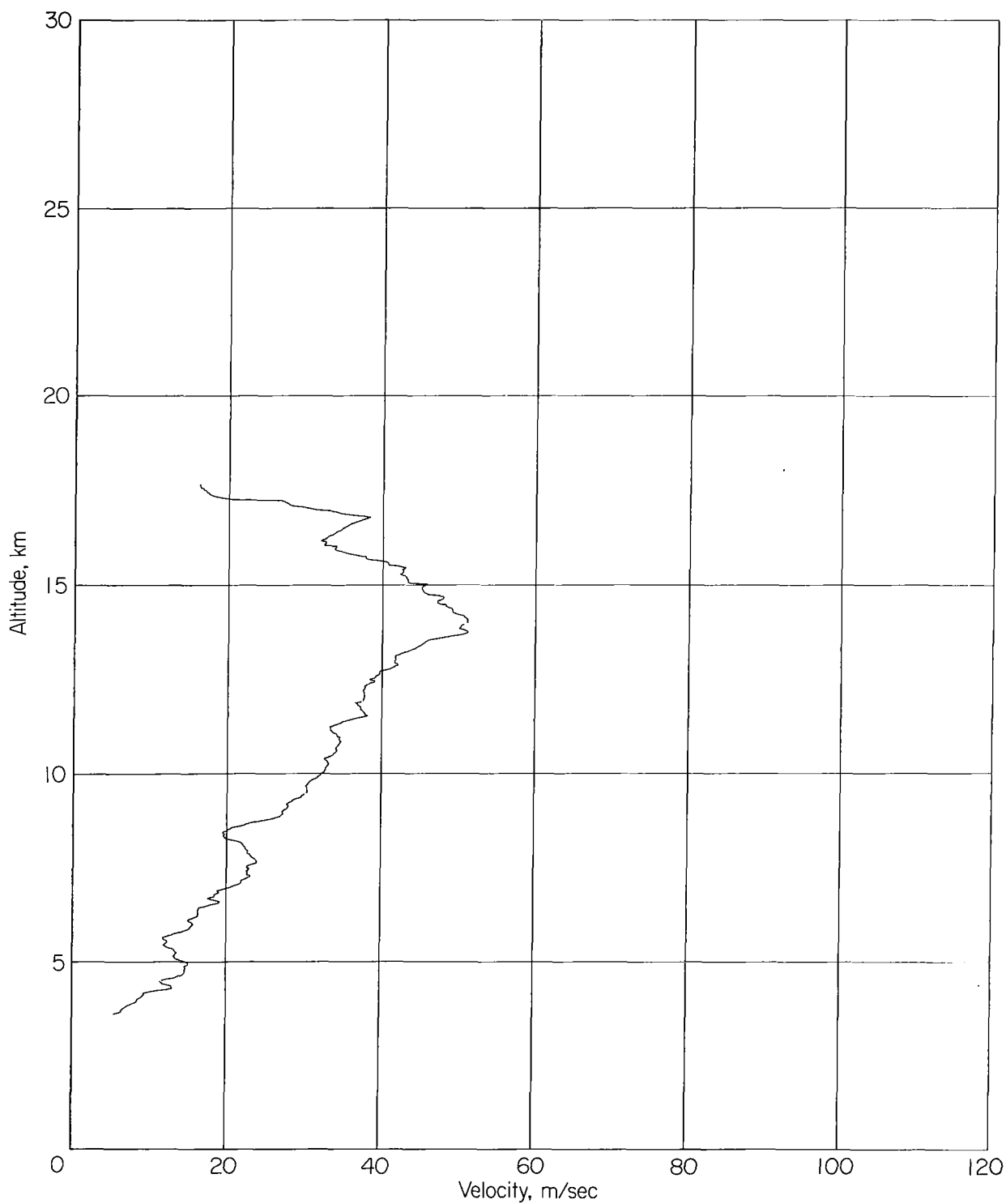
(a) West-to-east velocity component.

Figure 2.- Wind profile of smoke trail 381 obtained January 22, 1964.
Time interval, 60 seconds; height interval, 25 meters.



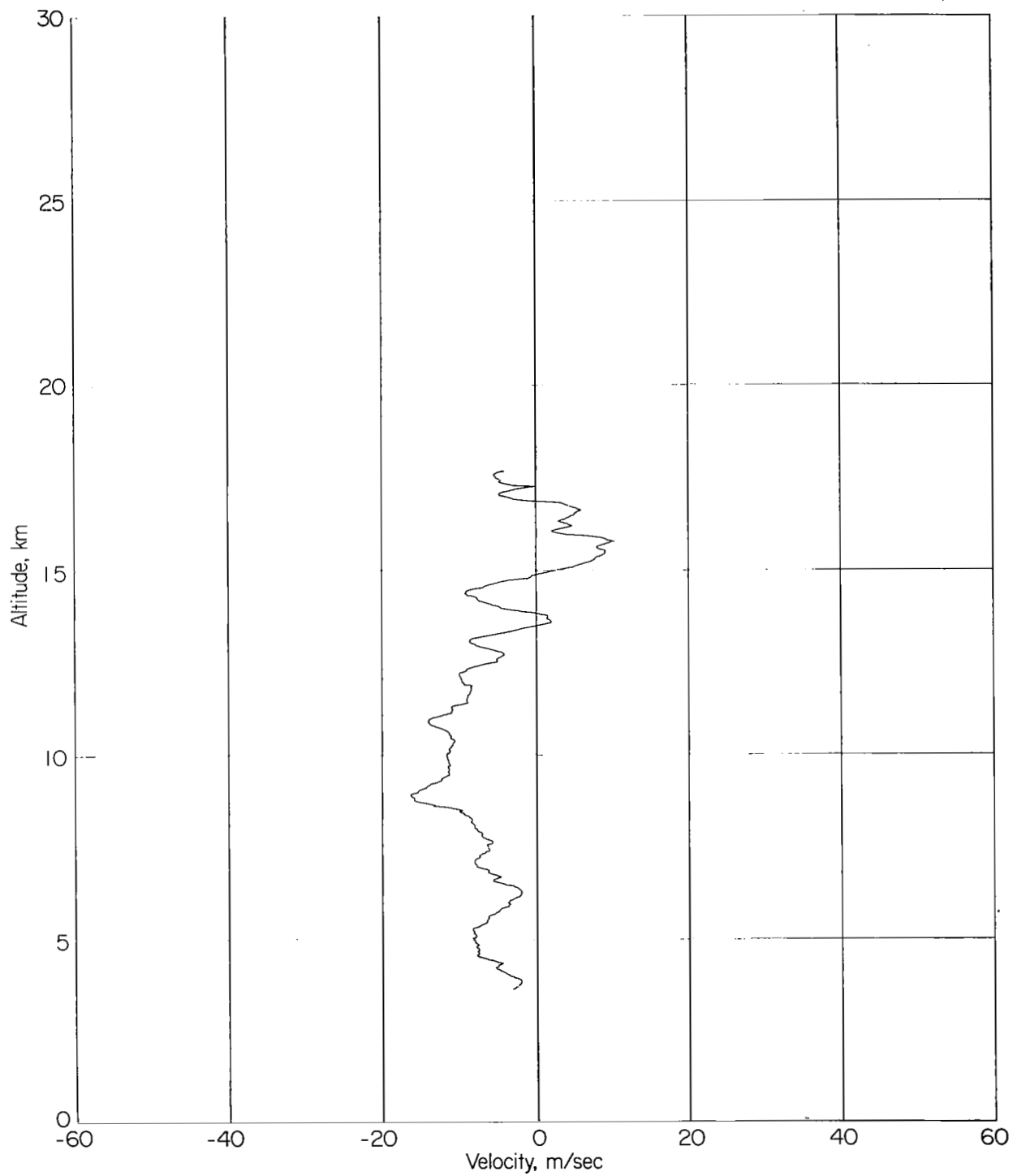
(b) South-to-north velocity component.

Figure 2.- Concluded.



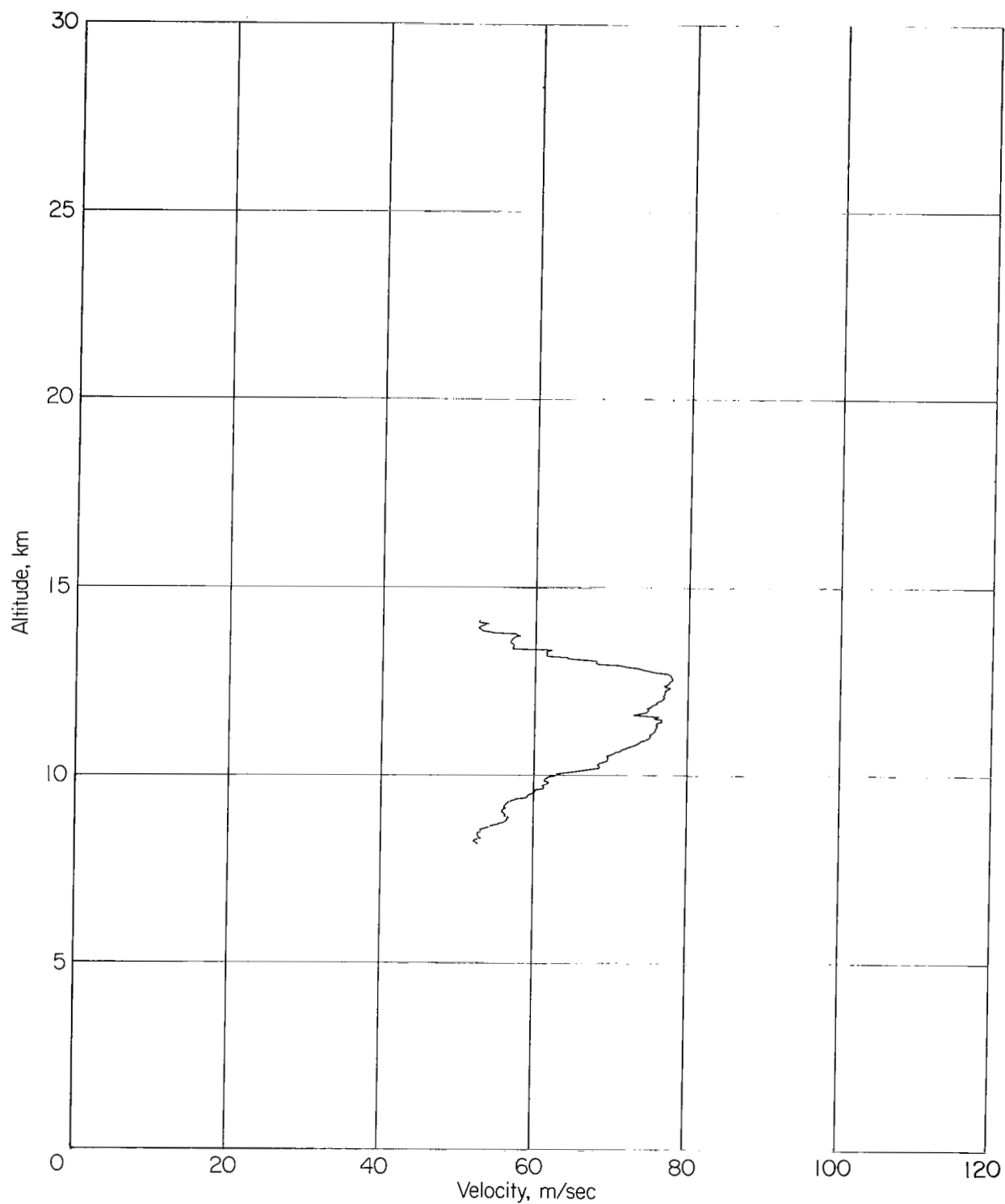
(a) West-to-east velocity component.

Figure 3.- Wind profile of smoke trail 382 obtained January 24, 1964.
Time interval, 60 seconds; height interval, 25 meters.



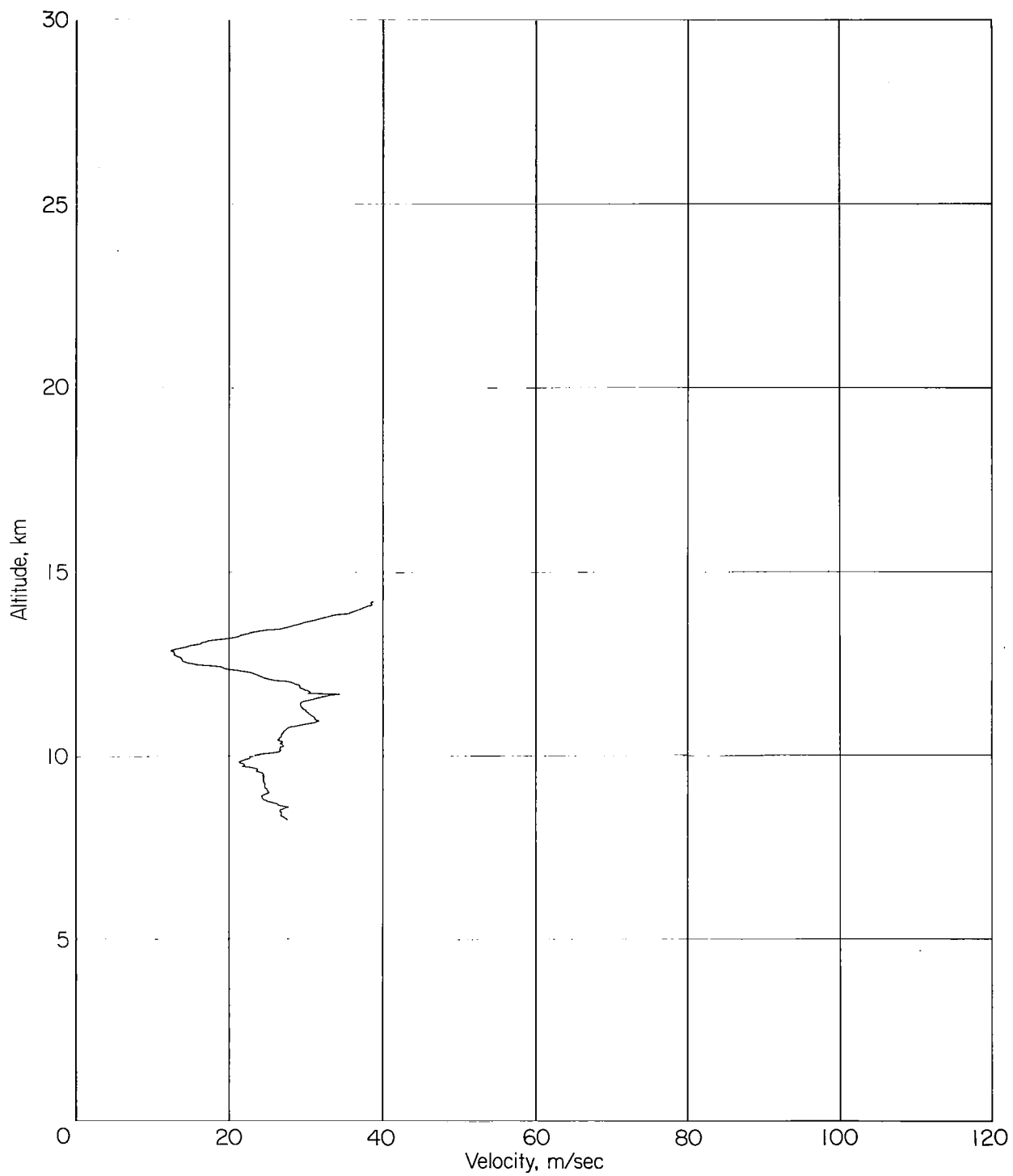
(b) South-to-north velocity component.

Figure 3.- Concluded.



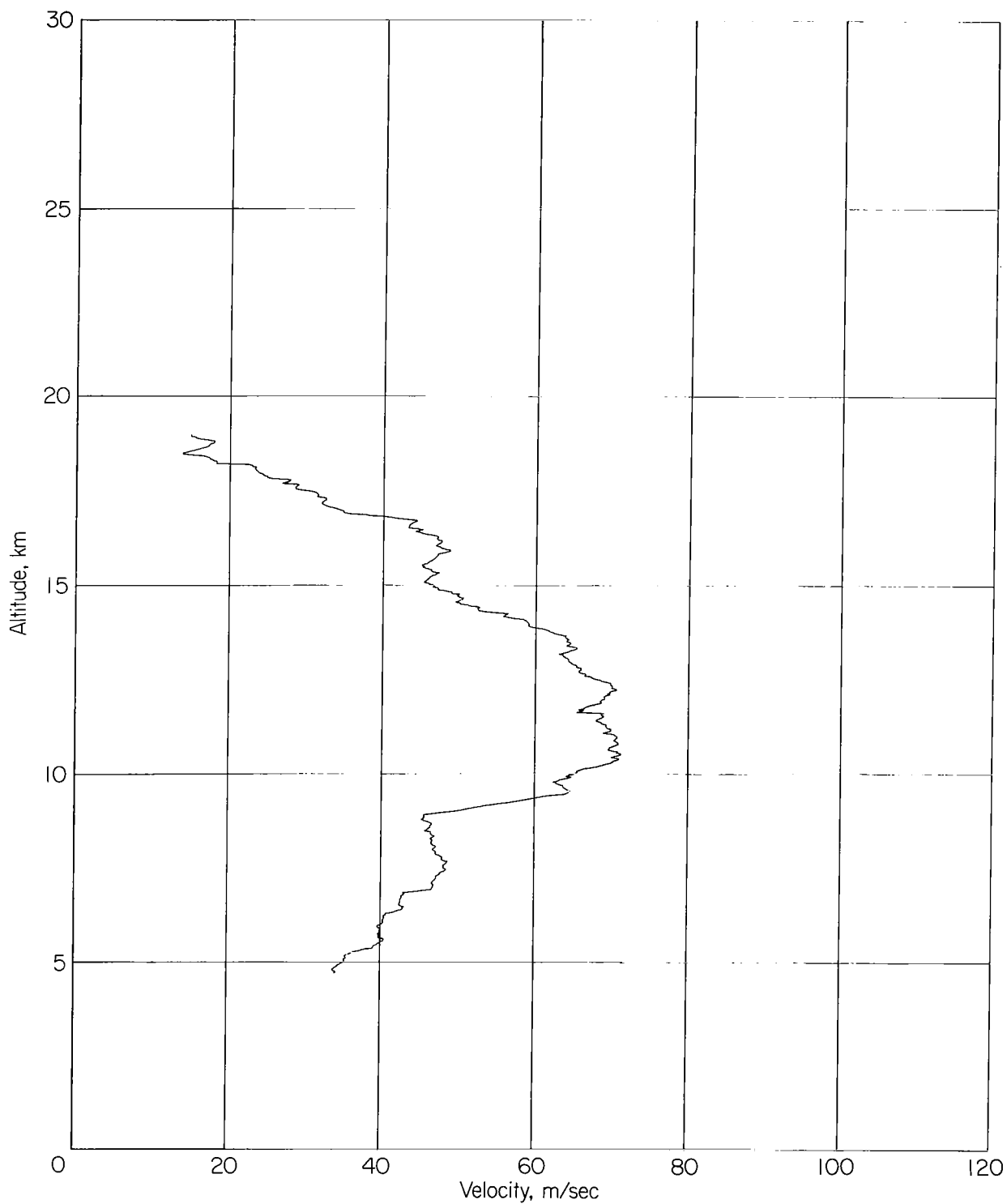
(a) West-to-east velocity component.

Figure 4.- Wind profile of smoke trail 383 obtained February 19, 1964.
Time interval, 60 seconds; height interval, 25 meters.



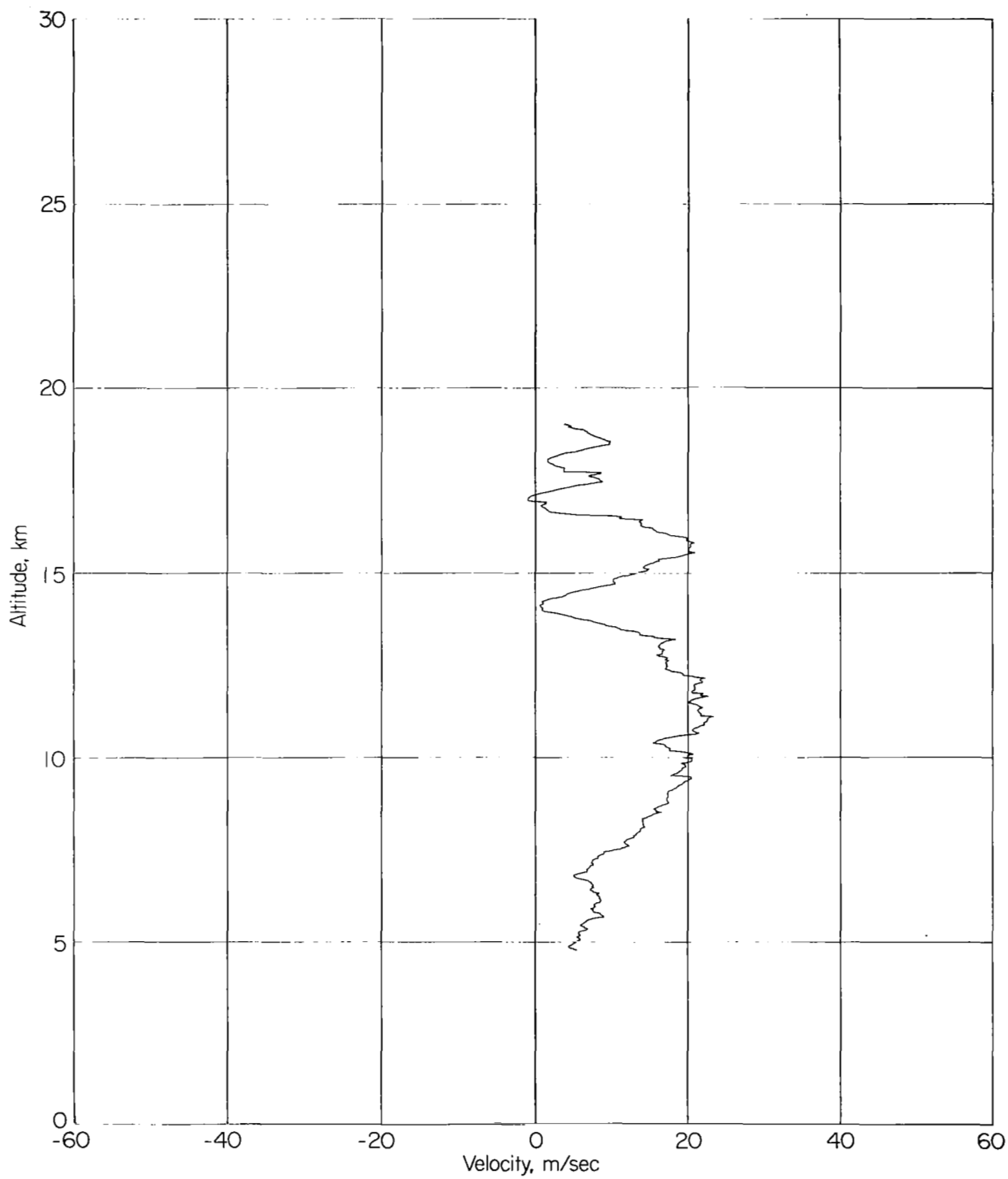
(b) South-to-north velocity component.

Figure 4.- Concluded.



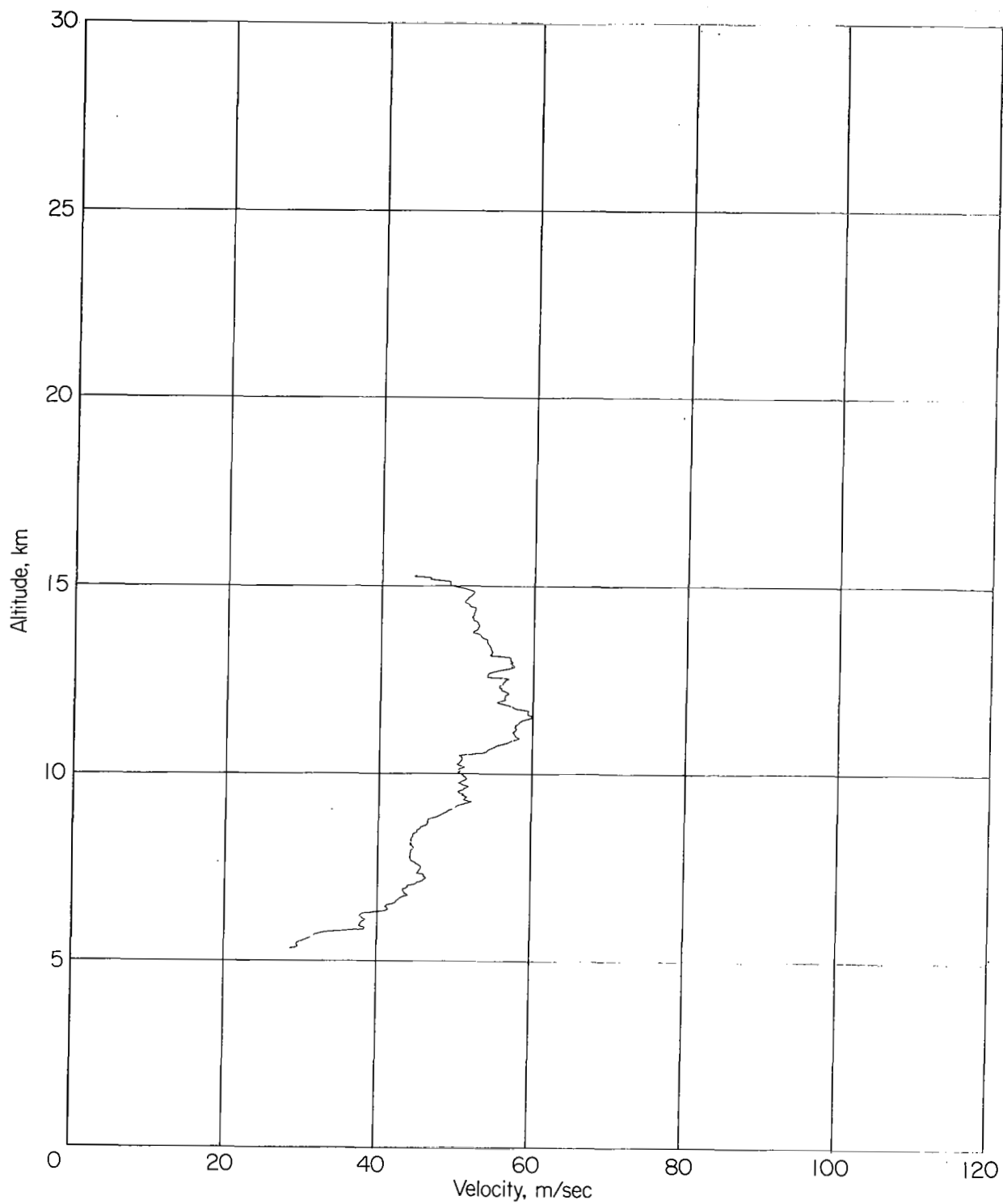
(a) West-to-east velocity component.

Figure 5.- Wind profile of smoke trail 384 obtained February 20, 1964.
Time interval, 60 seconds; height interval, 25 meters.



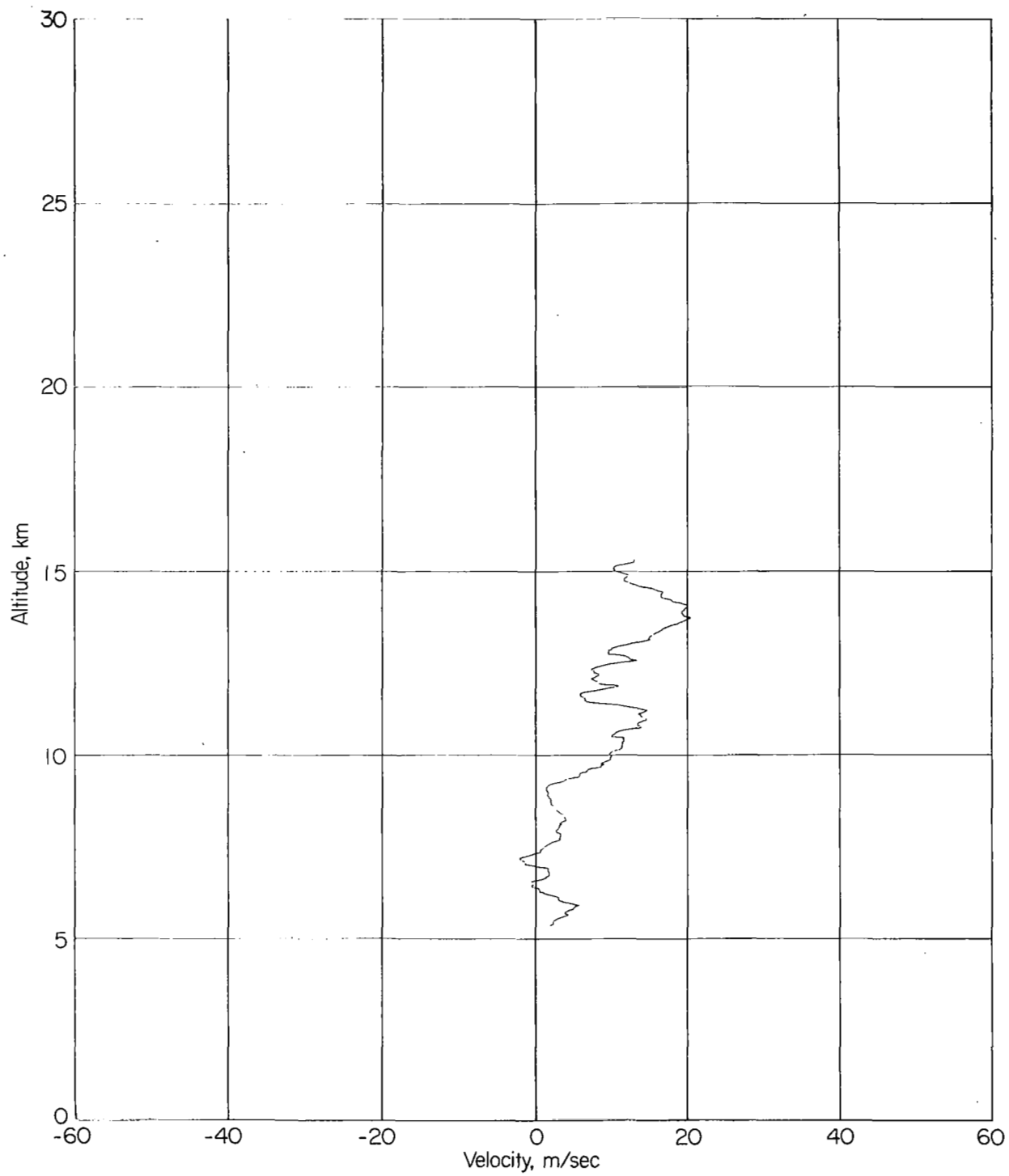
(b) South-to-north velocity component.

Figure 5.- Concluded.



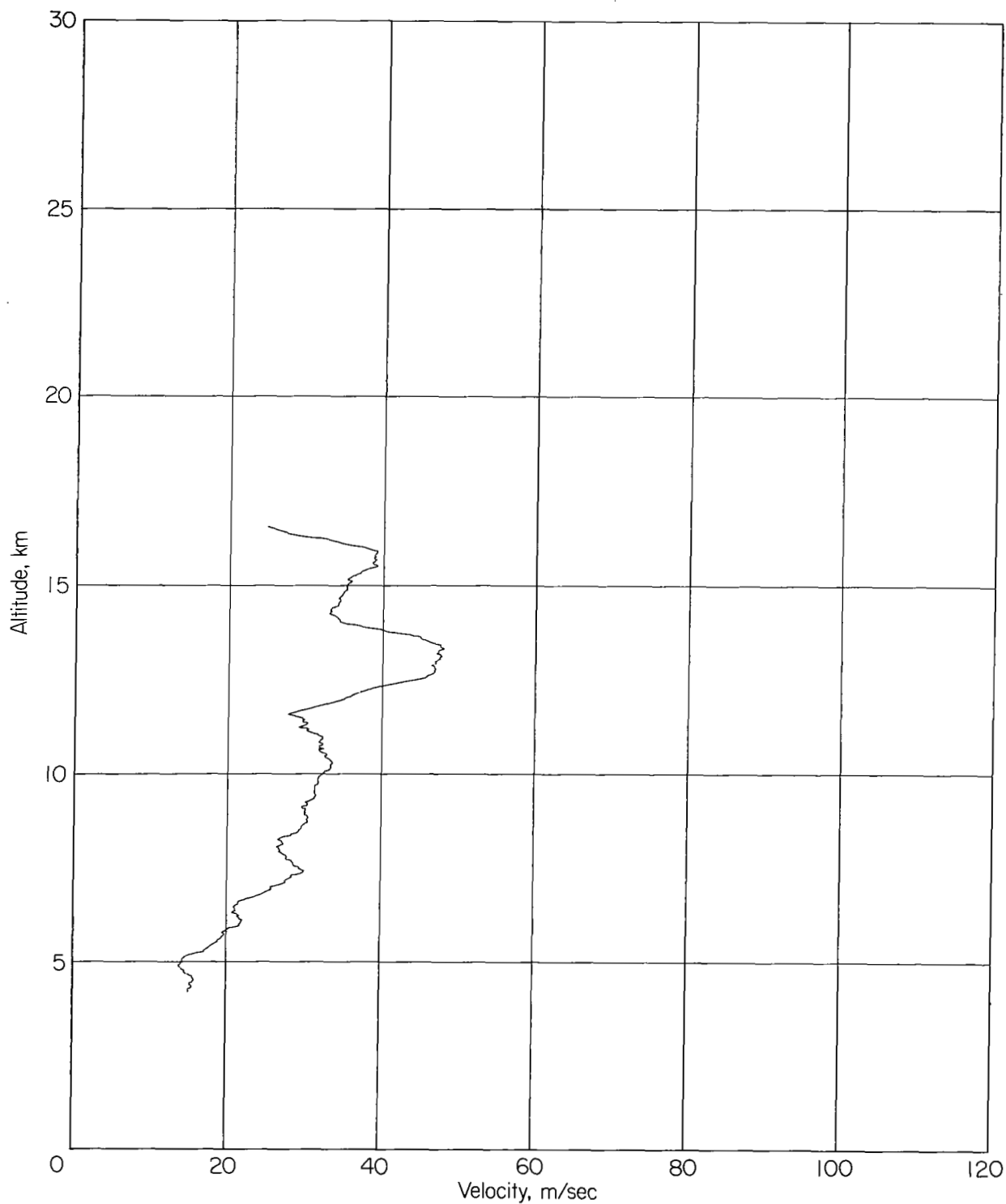
(a) West-to-east velocity component.

Figure 6.- Wind profile of smoke trail 385 obtained February 26, 1964.
Time interval, 60 seconds; height interval, 25 meters.



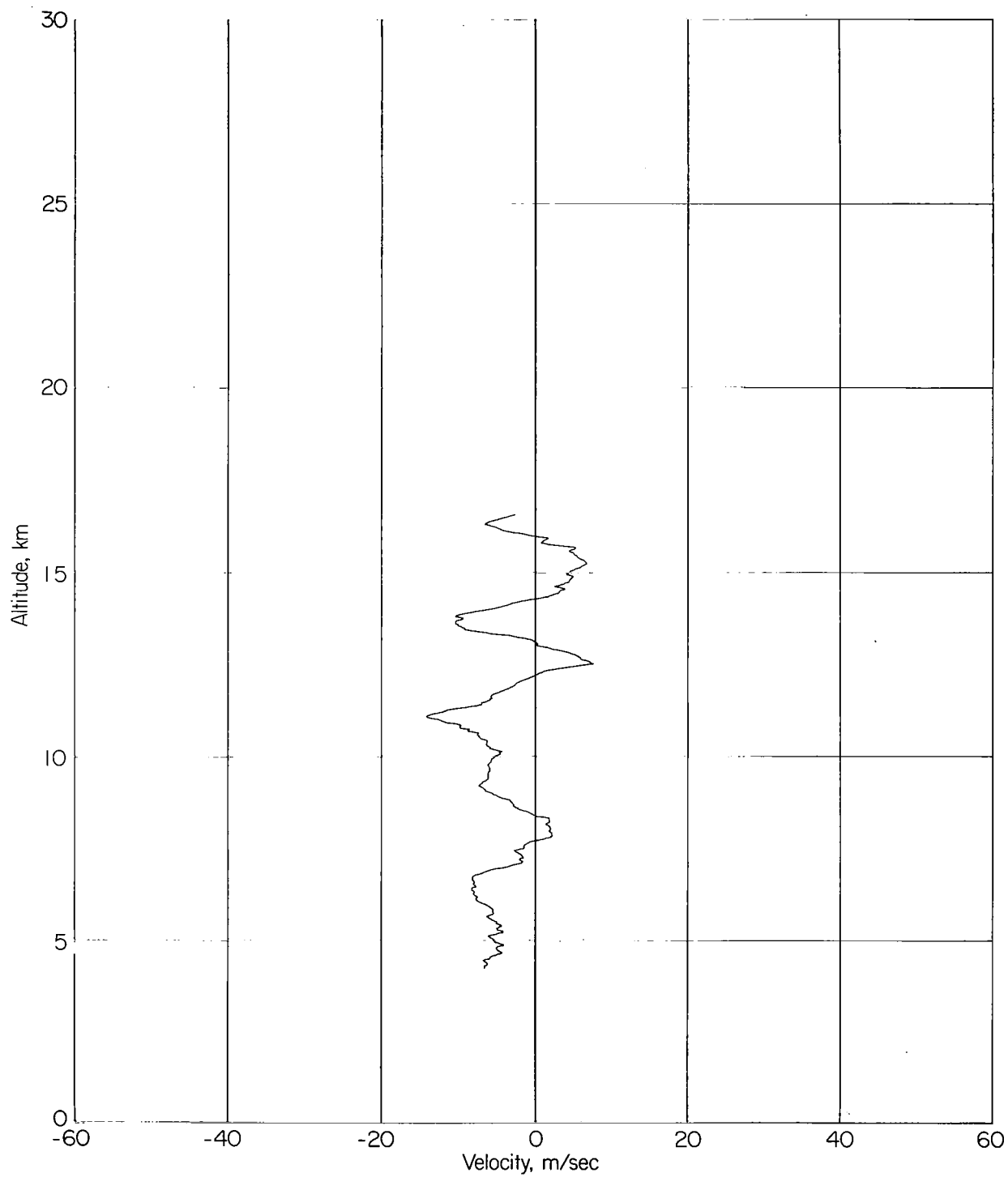
(b) South-to-north velocity component.

Figure 6.- Concluded.



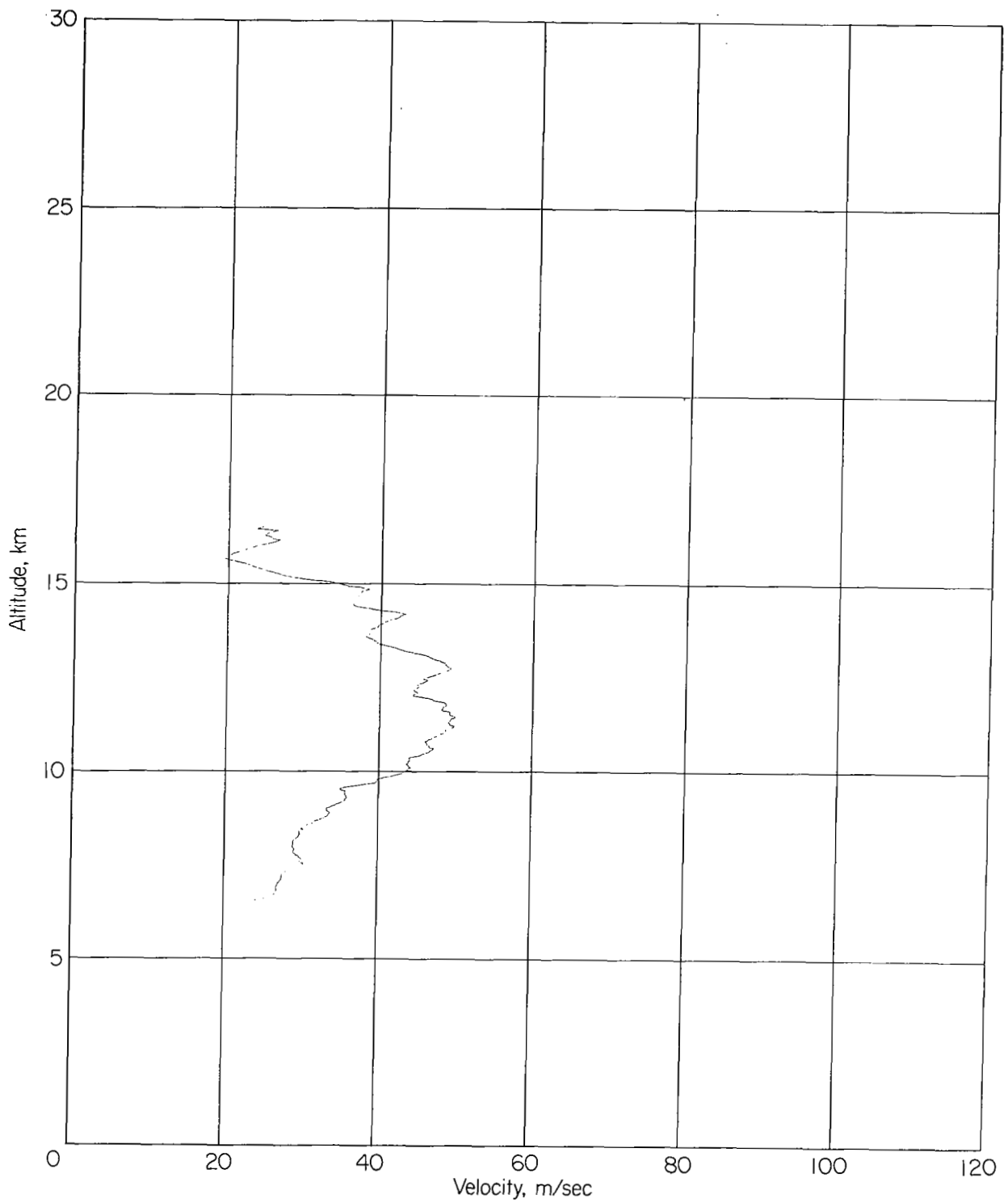
(a) West-to-east velocity component.

Figure 7.- Wind profile of smoke trail 386 obtained March 13, 1964.
Time interval, 60 seconds; height interval, 25 meters.



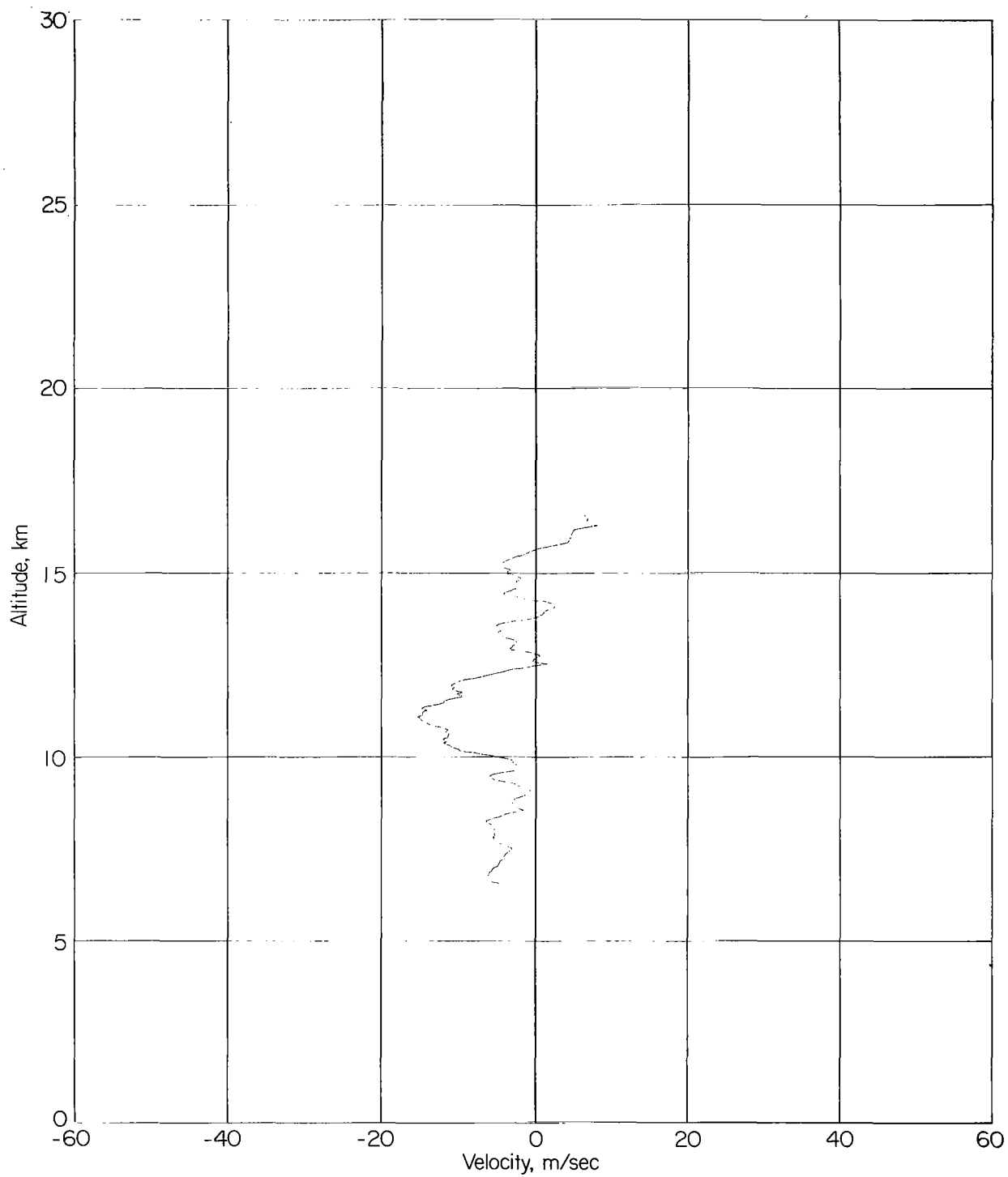
(b) South-to-north velocity component.

Figure 7.- Concluded.



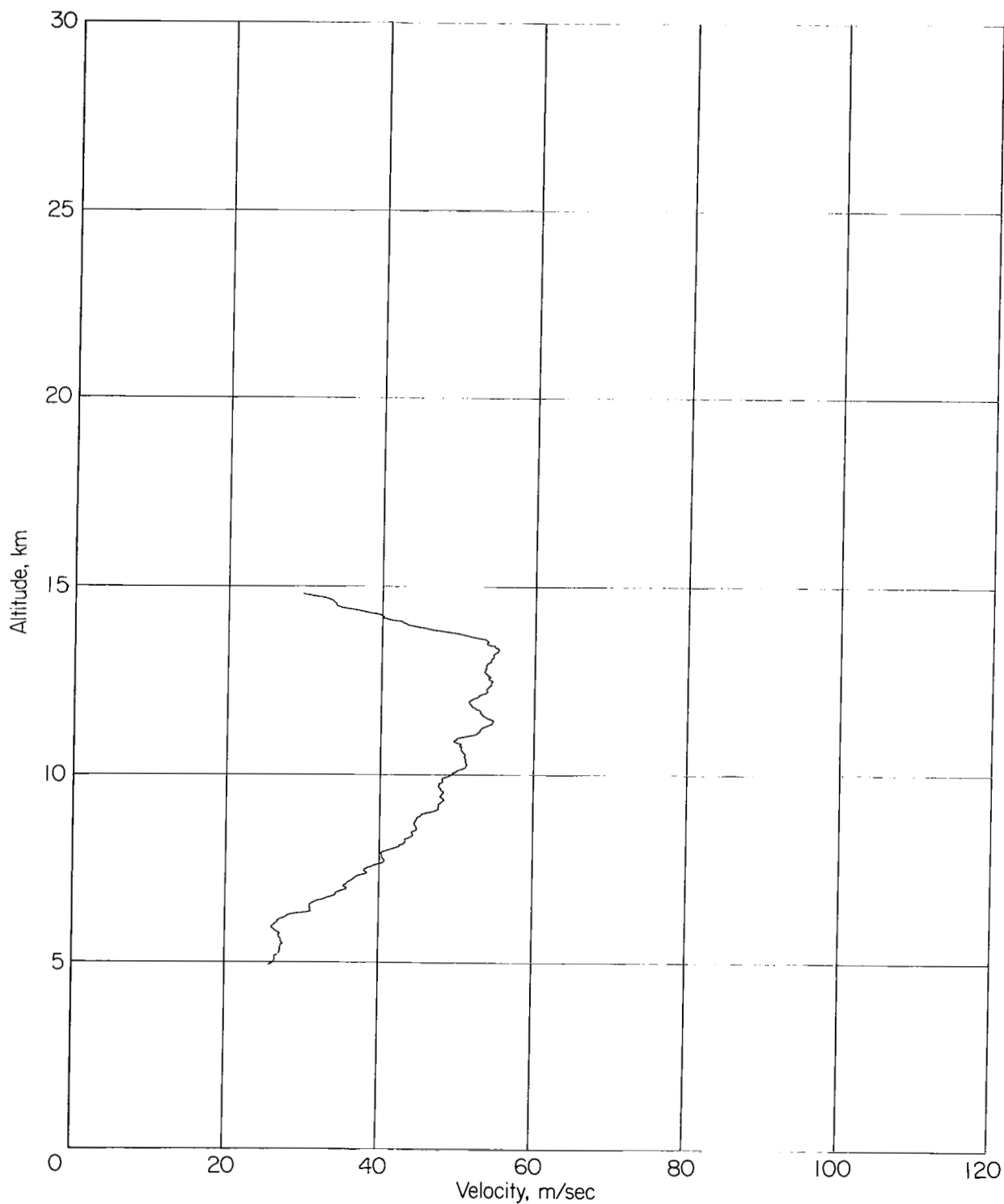
(a) West-to-east velocity component.

Figure 8.- Wind profile of smoke trail 387 obtained March 18, 1964.
Time interval, 60 seconds; height interval, 25 meters.



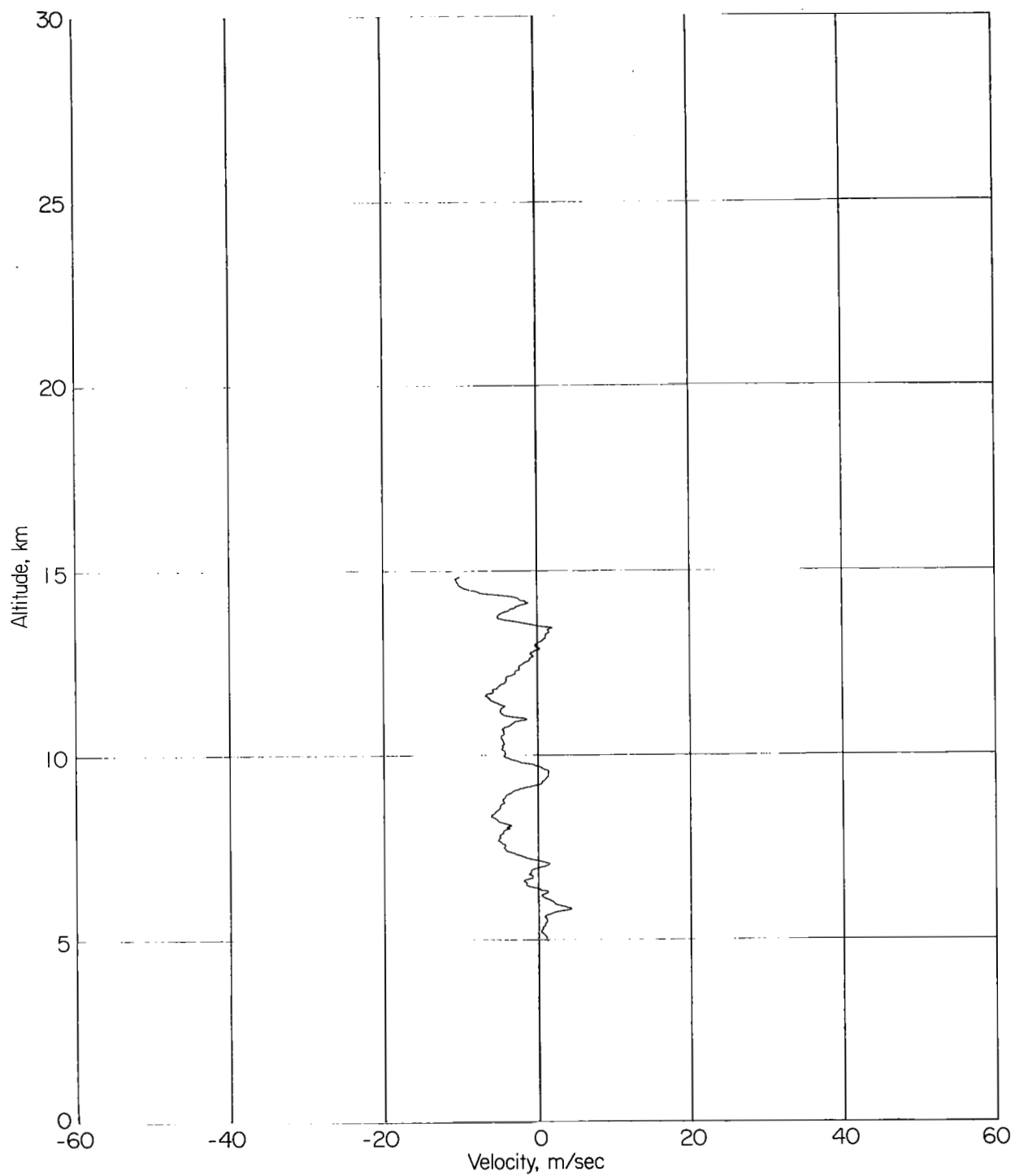
(b) South-to-north velocity component.

Figure 8.- Concluded.



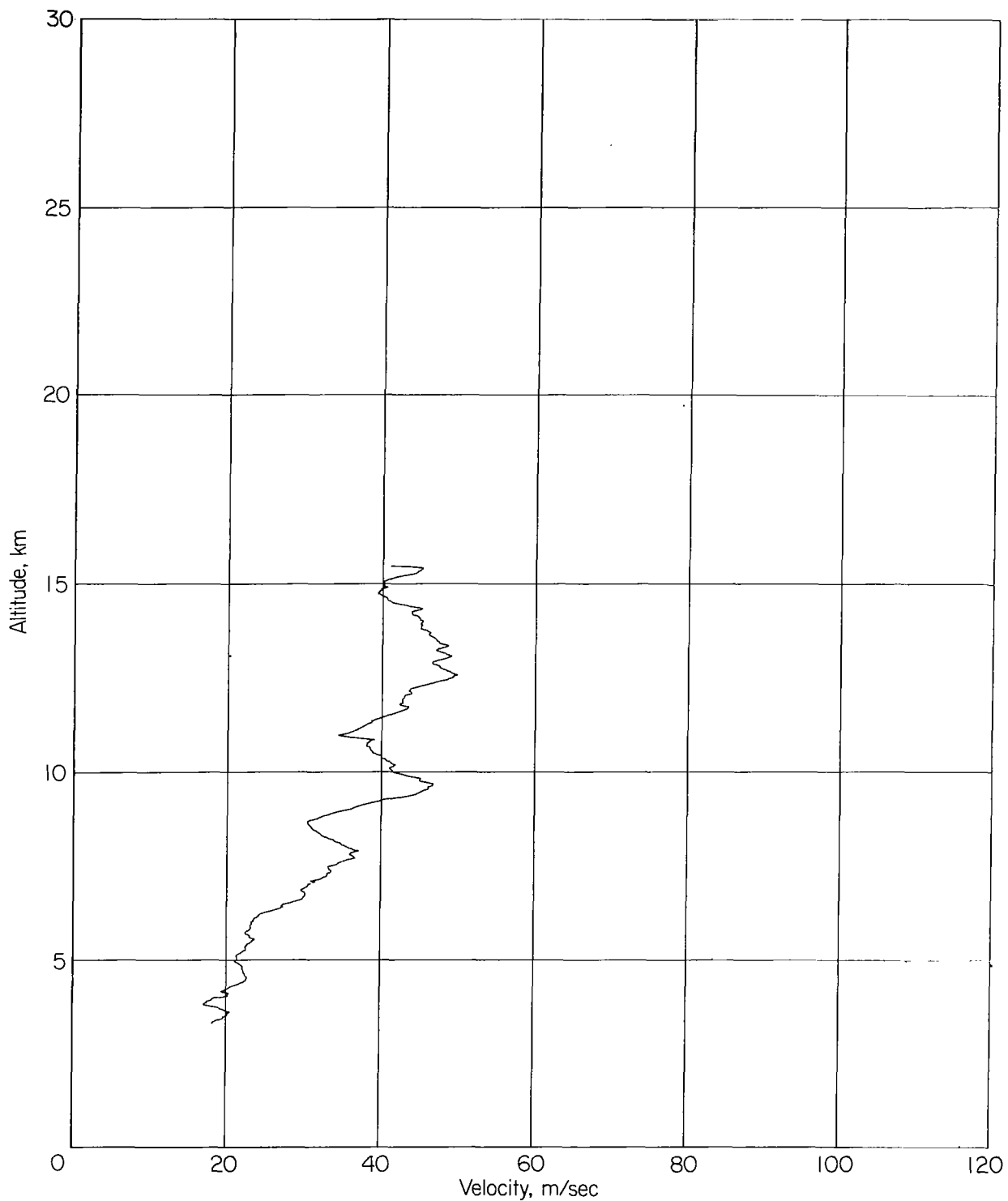
(a) West-to-east velocity component.

Figure 9.- Wind profile of smoke trail 388 obtained March 20, 1964.
Time interval, 60 seconds; height interval, 25 meters.



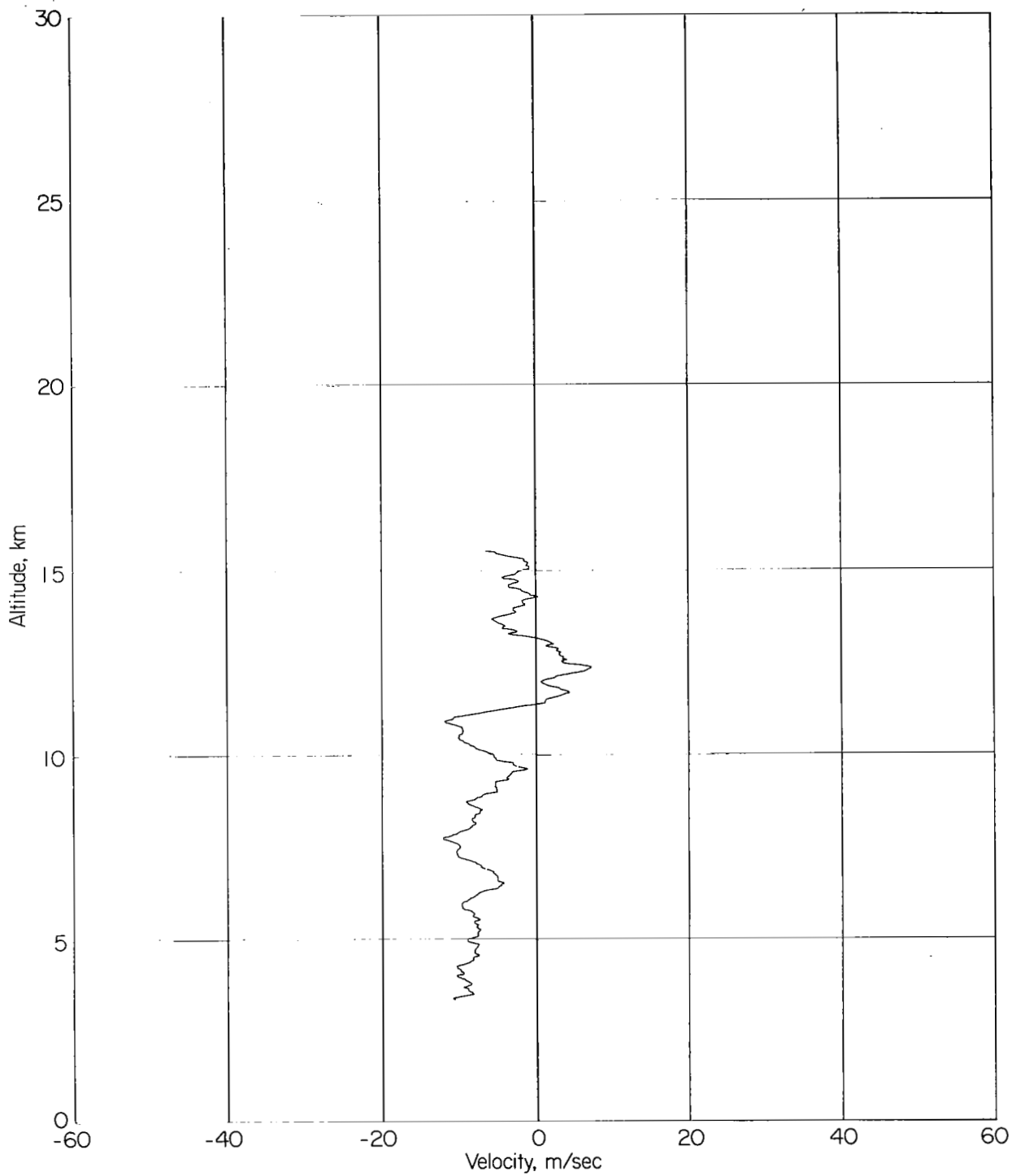
(b) South-to-north velocity component.

Figure 9.- Concluded.



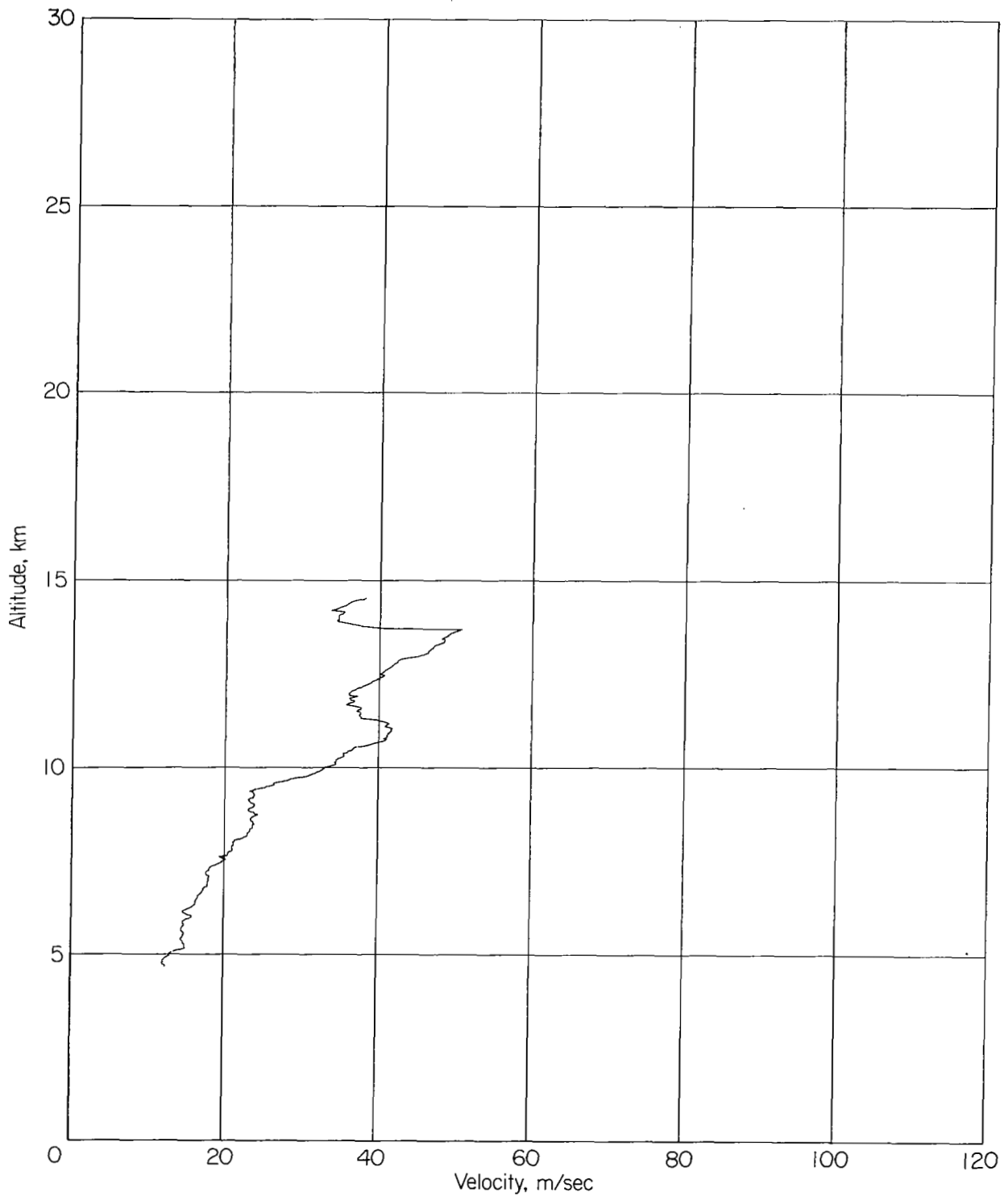
(a) West-to-east velocity component.

Figure 10.- Wind profile of smoke trail 389 obtained March 31, 1964.
Time interval, 60 seconds; height interval, 25 meters.



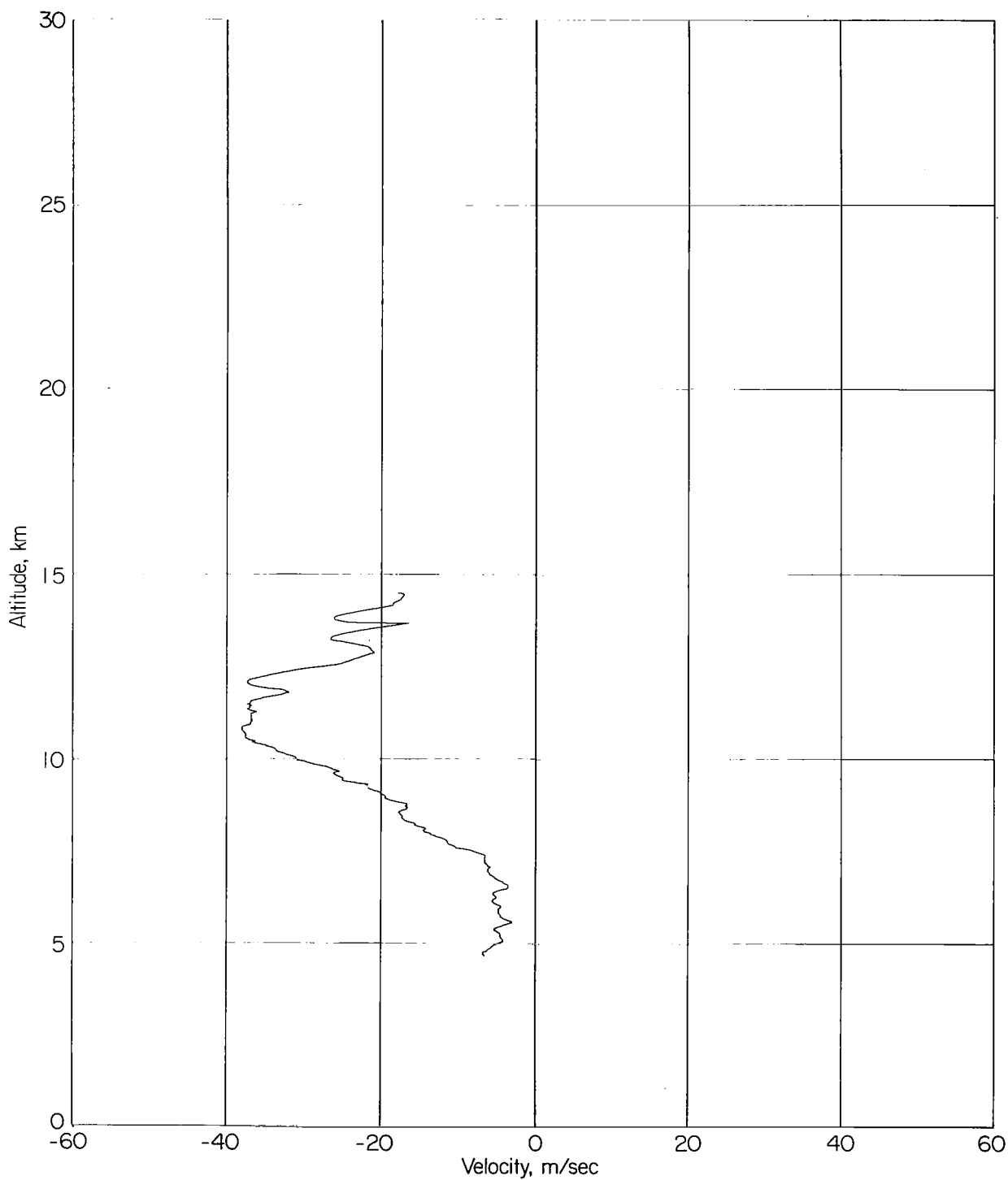
(b) South-to-north velocity component.

Figure 10.- Concluded.



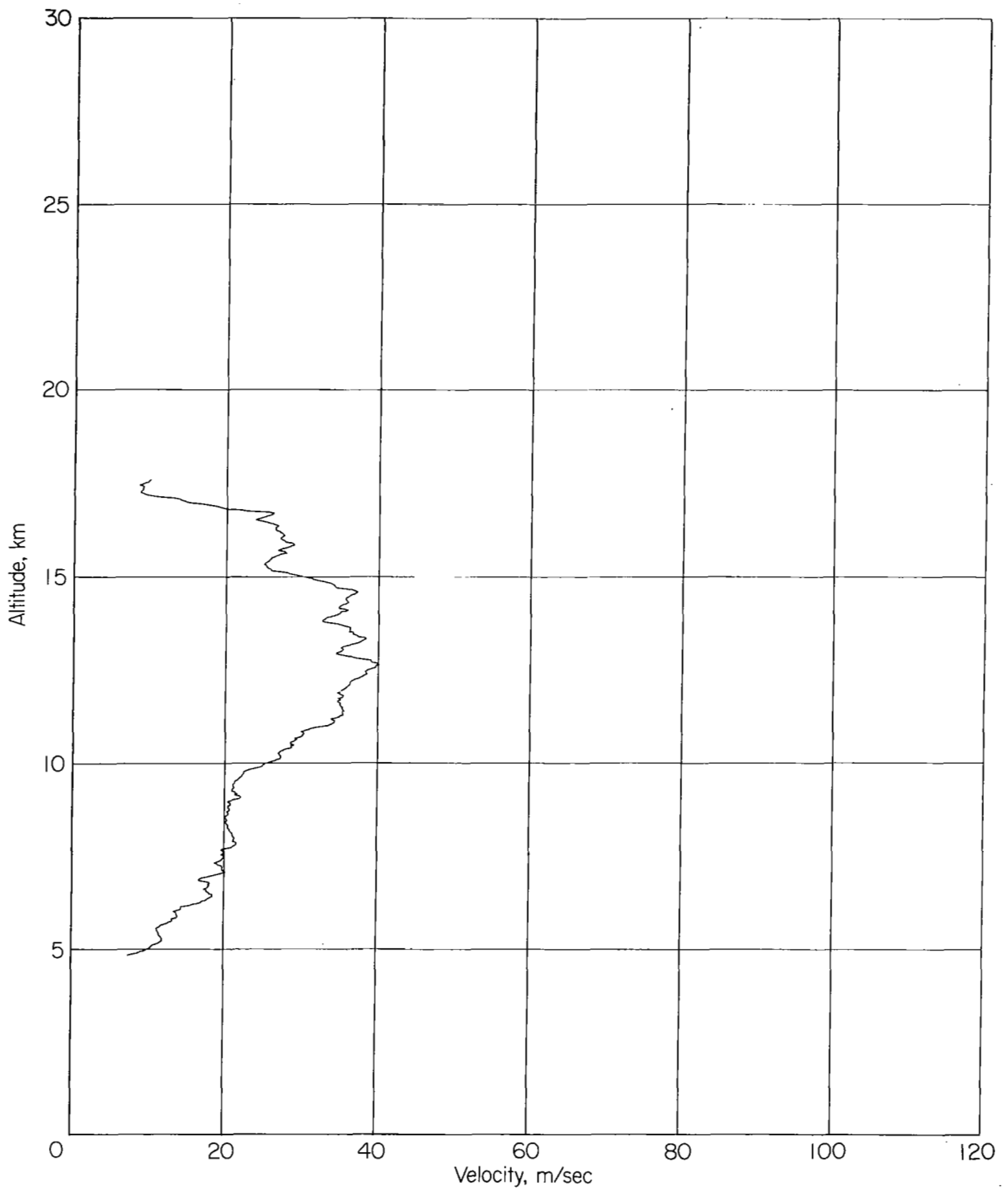
(a) West-to-east velocity component.

Figure 11.- Wind profile of smoke trail 390 obtained April 1, 1964.
Time interval, 60 seconds; height interval, 25 meters.



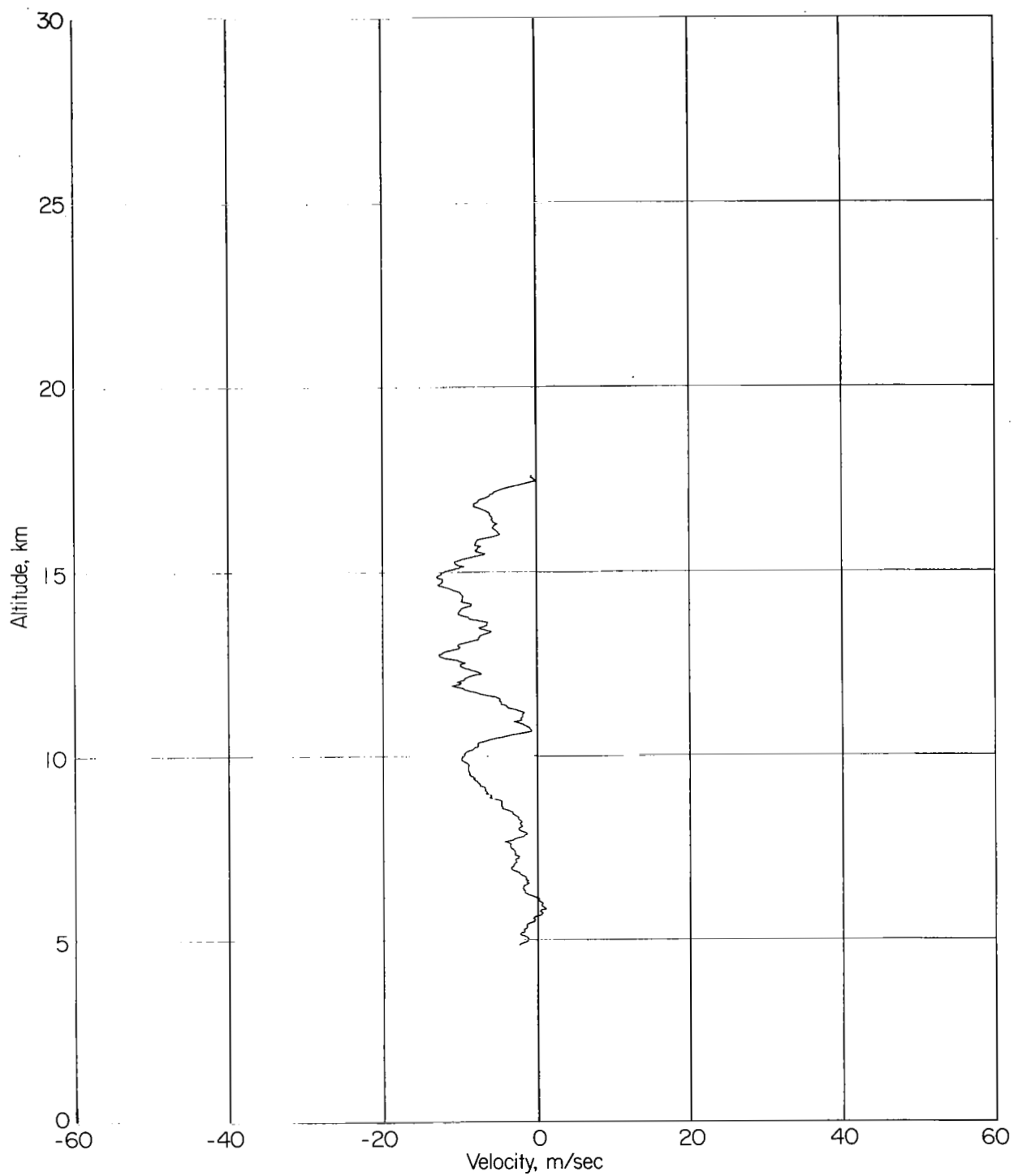
(b) South-to-north velocity component.

Figure 11.- Concluded.



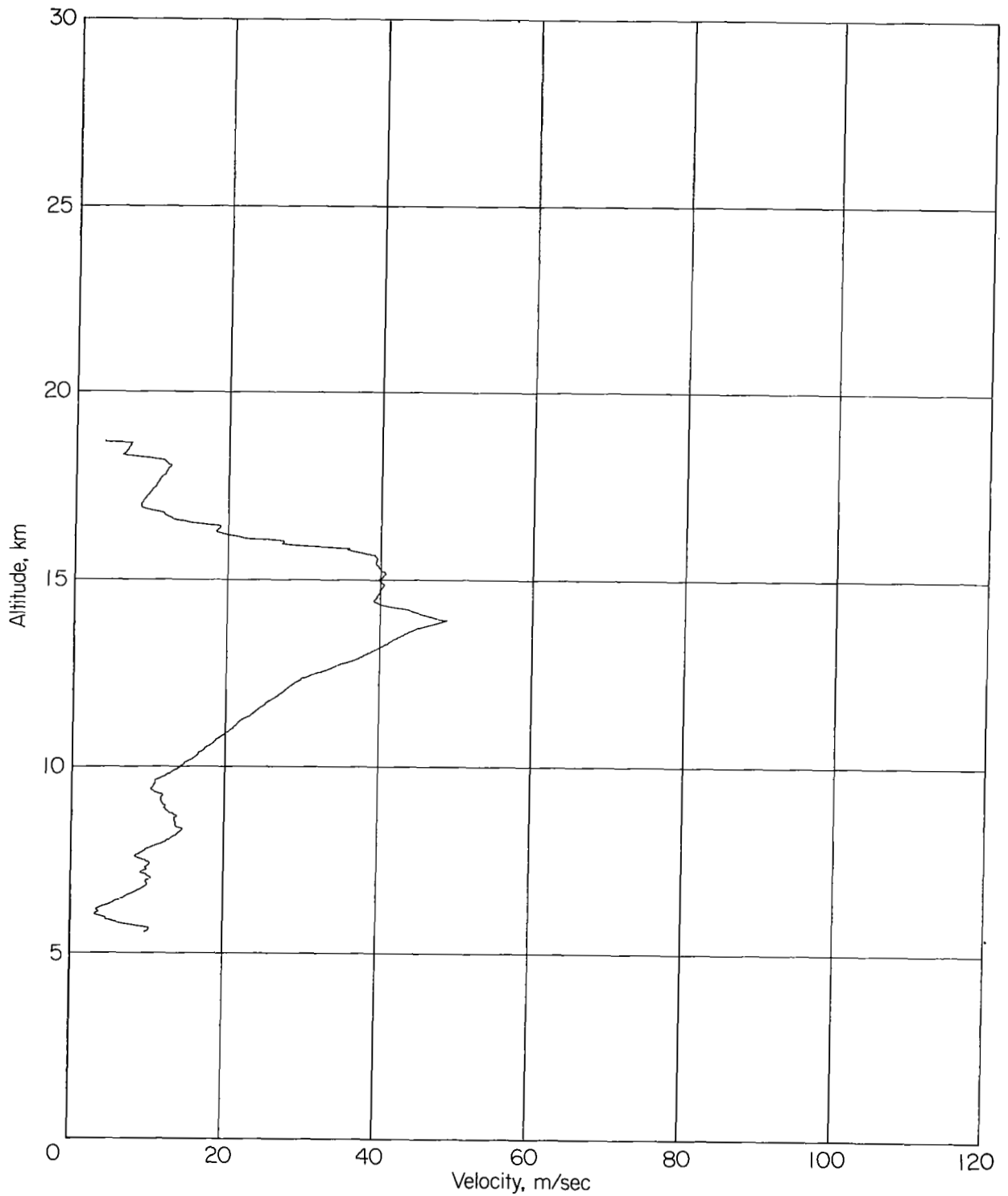
(a) West-to-east velocity component.

Figure 12.- Wind profile of smoke trail 391 obtained April 3, 1964.
Time interval, 60 seconds; height interval, 25 meters.



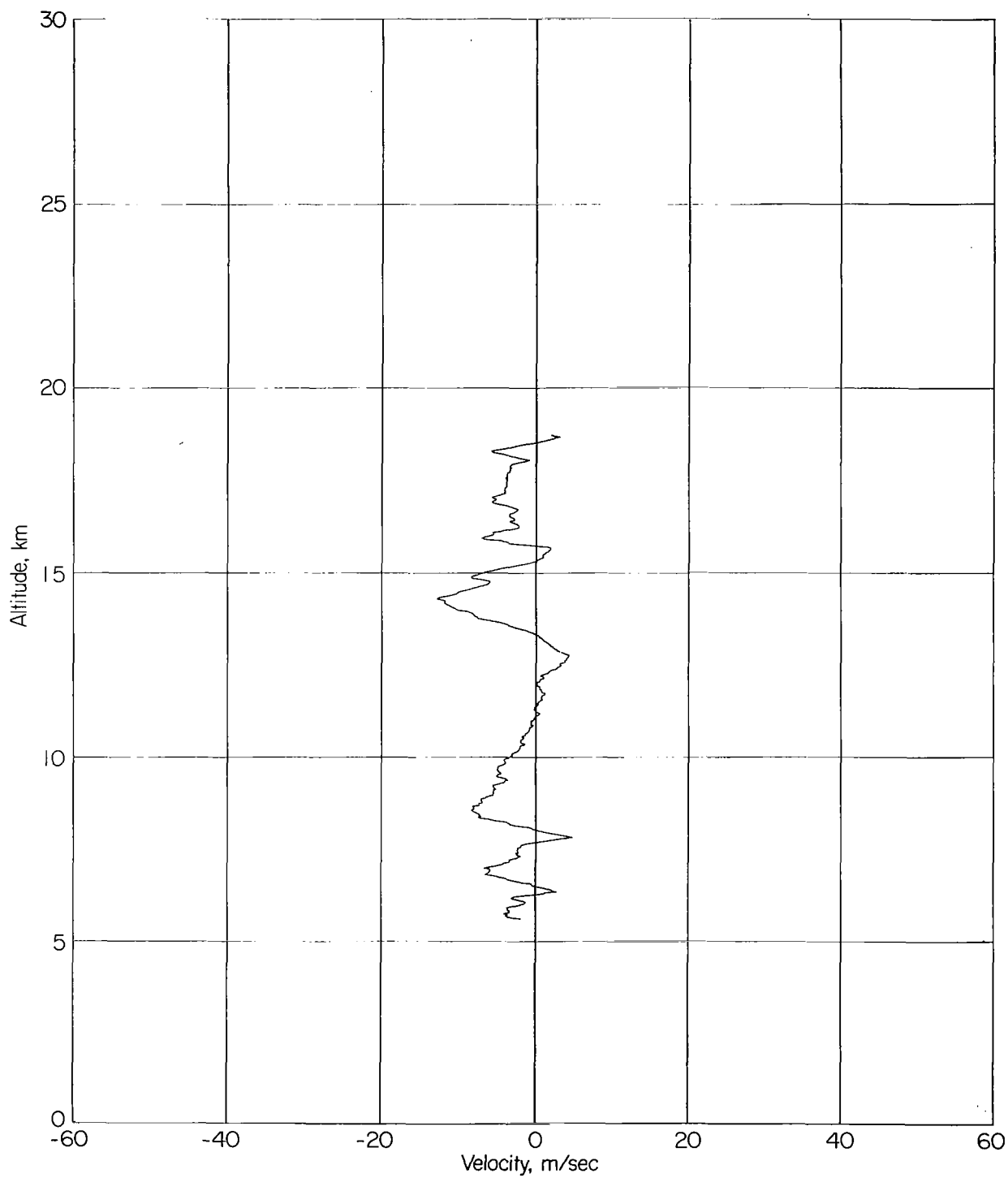
(b) South-to-north velocity component.

Figure 12.- Concluded.



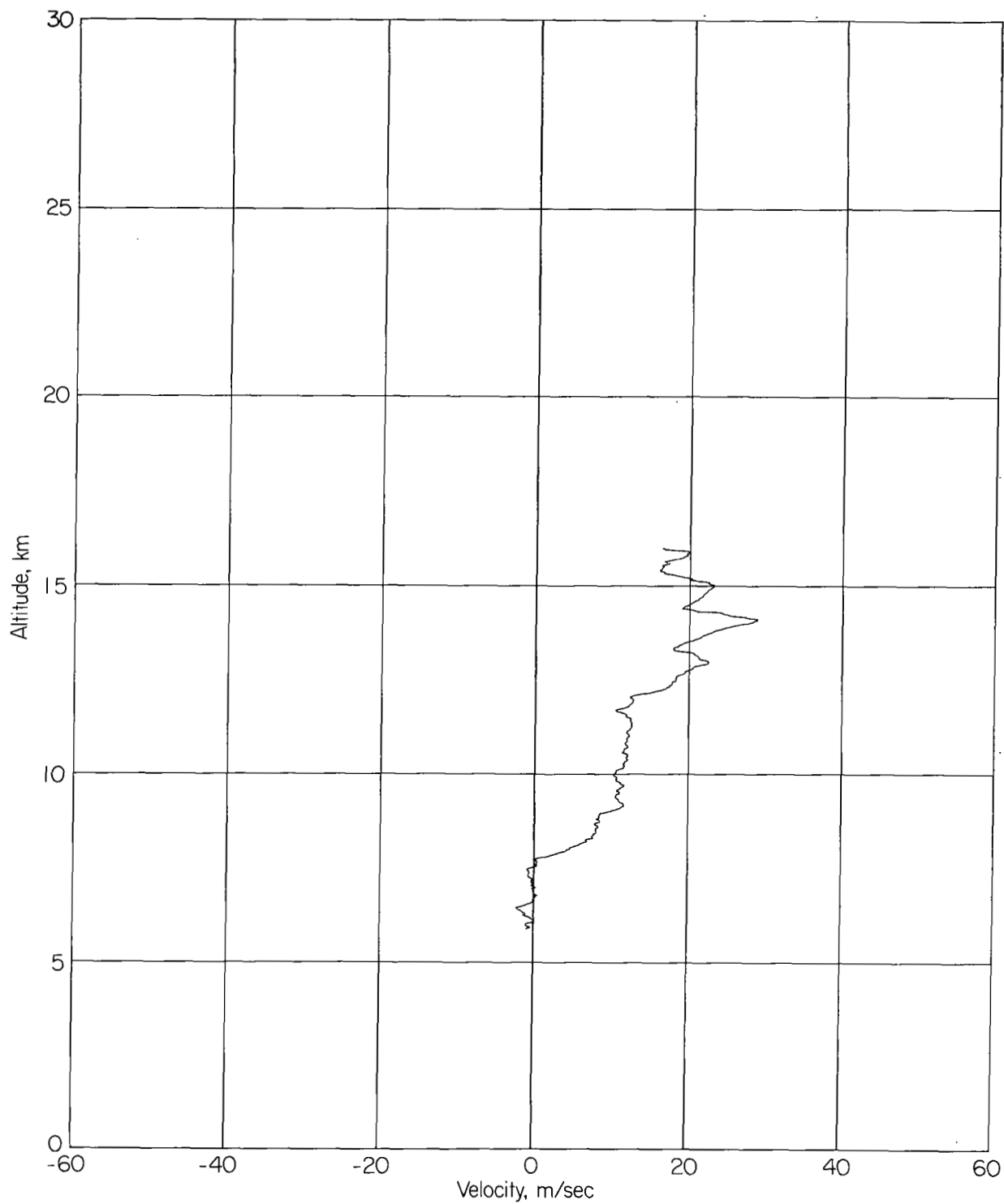
(a) West-to-east velocity component.

Figure 13.- Wind profile of smoke trail 392 obtained April 13, 1964.
Time interval, 60 seconds; height interval, 25 meters.



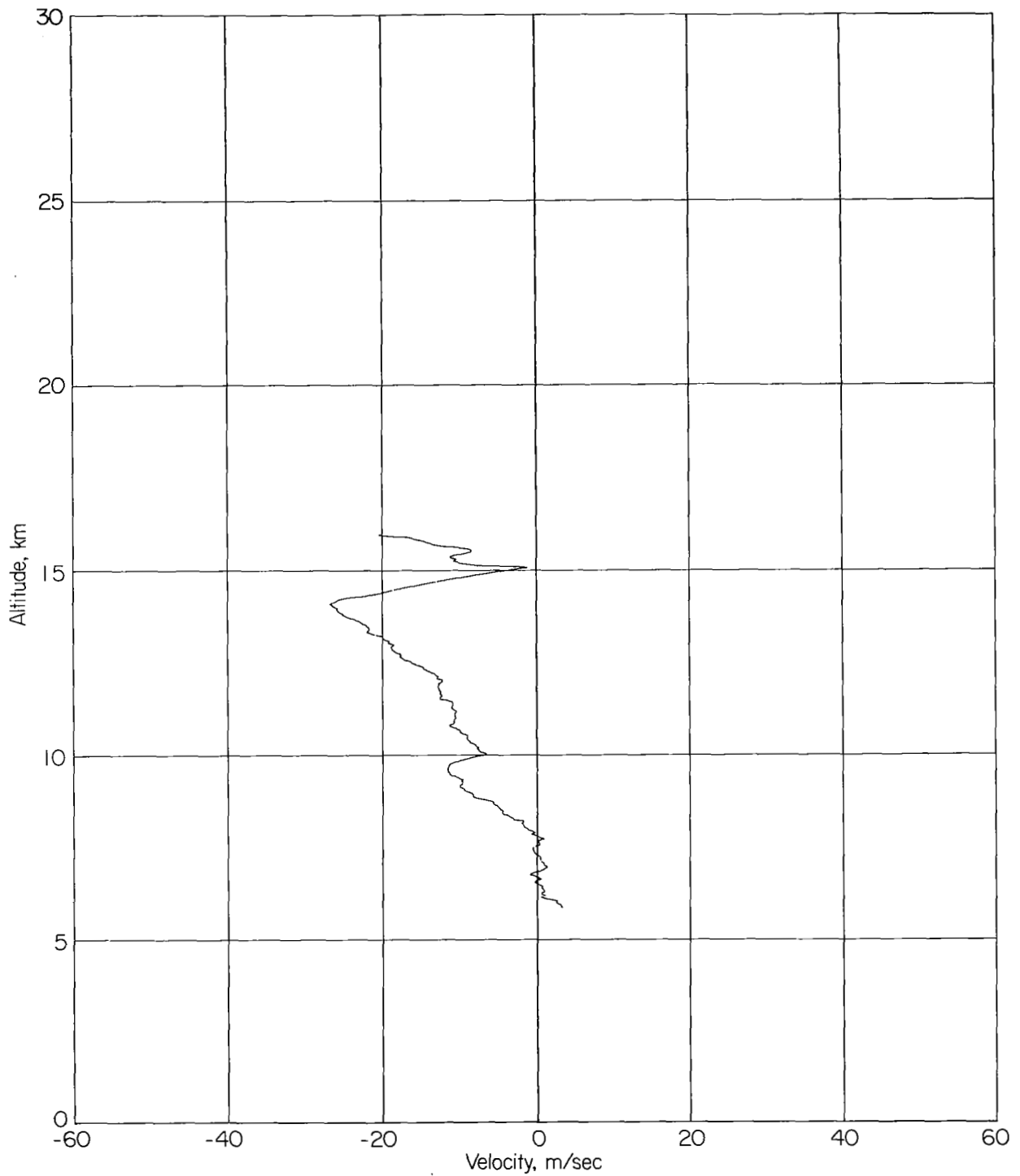
(b) South-to-north velocity component.

Figure 13.- Concluded.



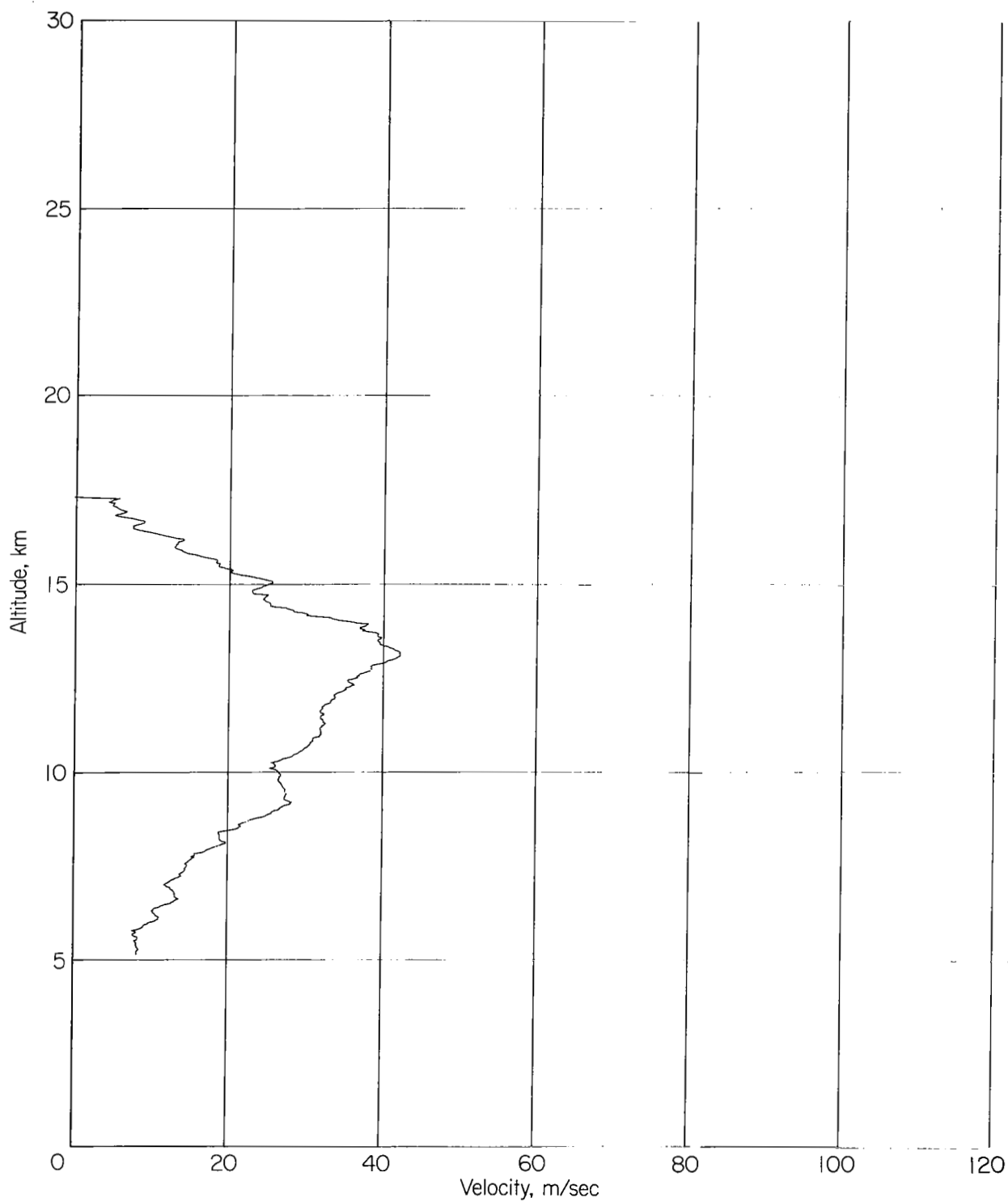
(a) West-to-east velocity component.

Figure 14.- Wind profile of smoke trail 393 obtained April 22, 1964.
Time interval, 60 seconds; height interval, 25 meters.



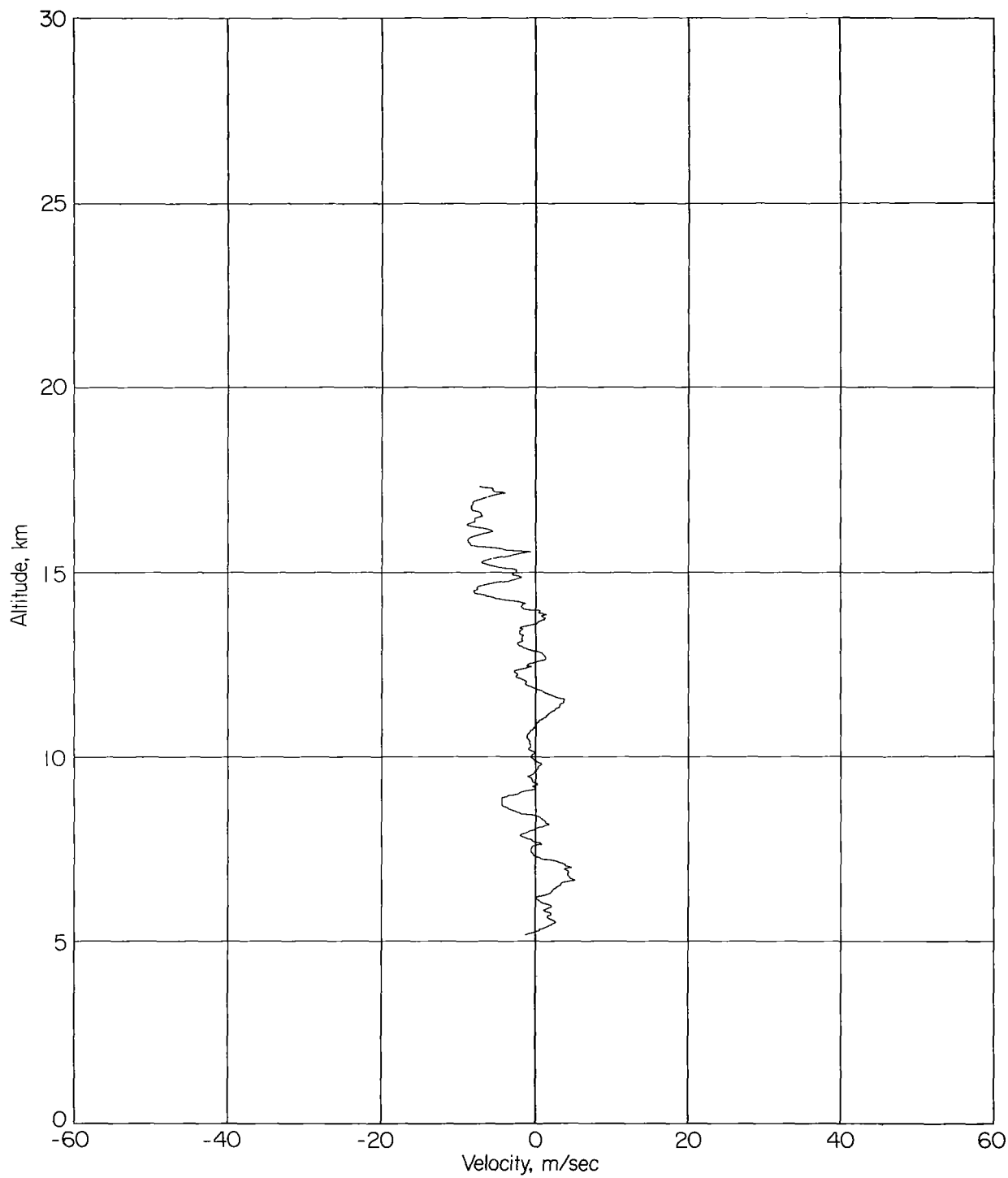
(b) South-to-north velocity component.

Figure 14.- Concluded.



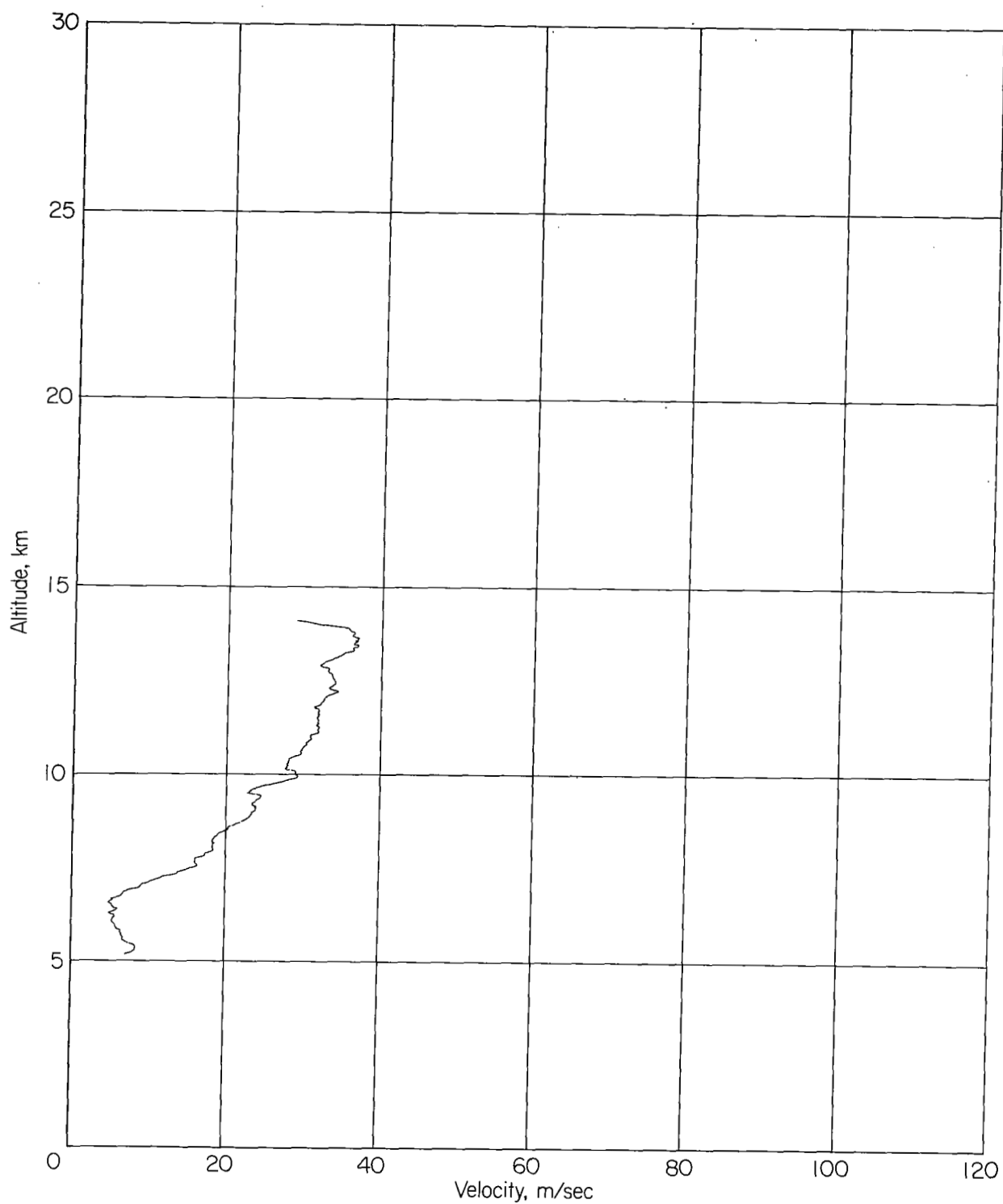
(a) West-to-east velocity component.

Figure 15.- Wind profile of smoke trail 394 obtained May 20, 1964.
Time interval, 60 seconds; height interval, 25 meters.



(b) South-to-north velocity component.

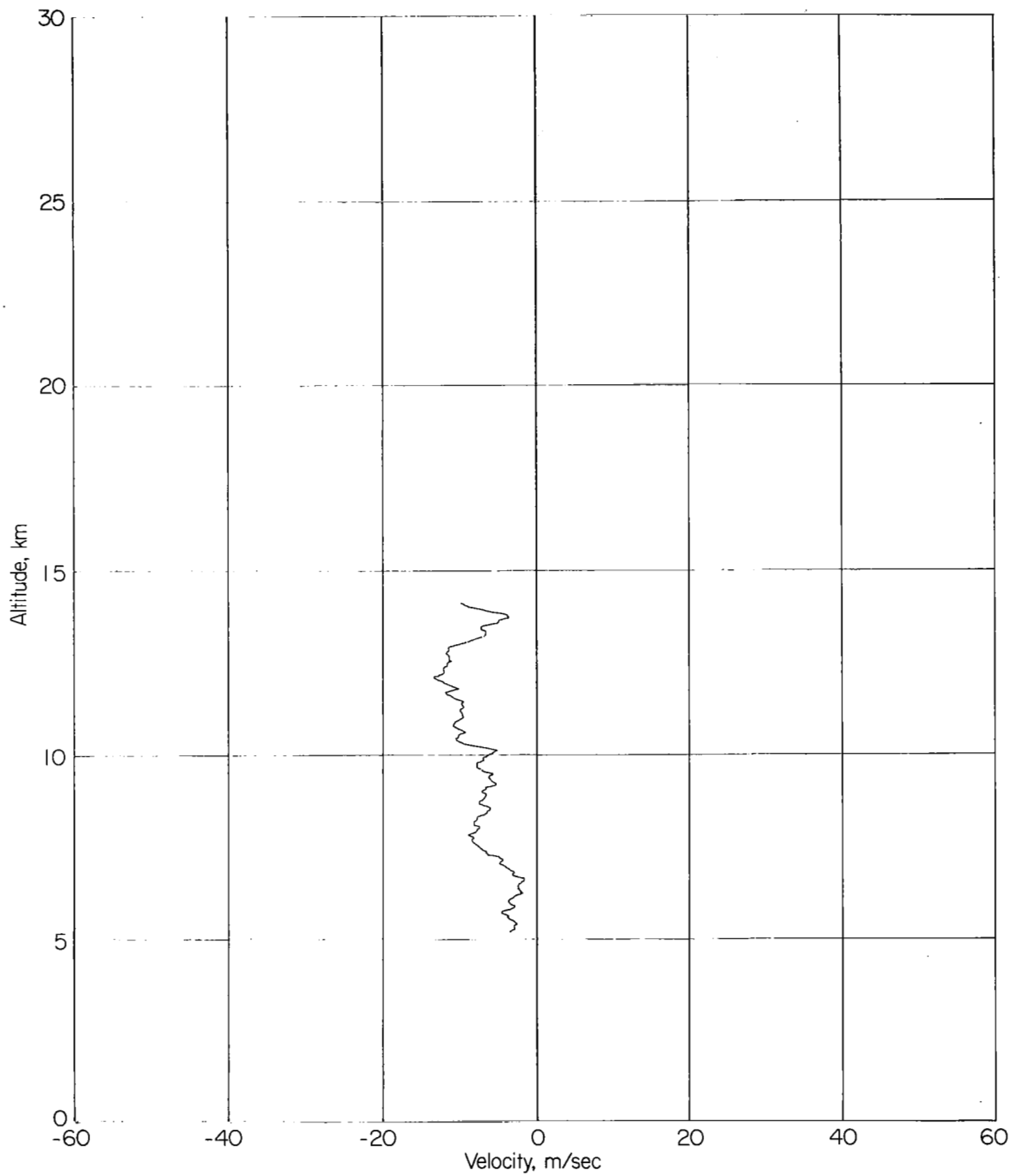
Figure 15.- Concluded.



(a) West-to-east velocity component.

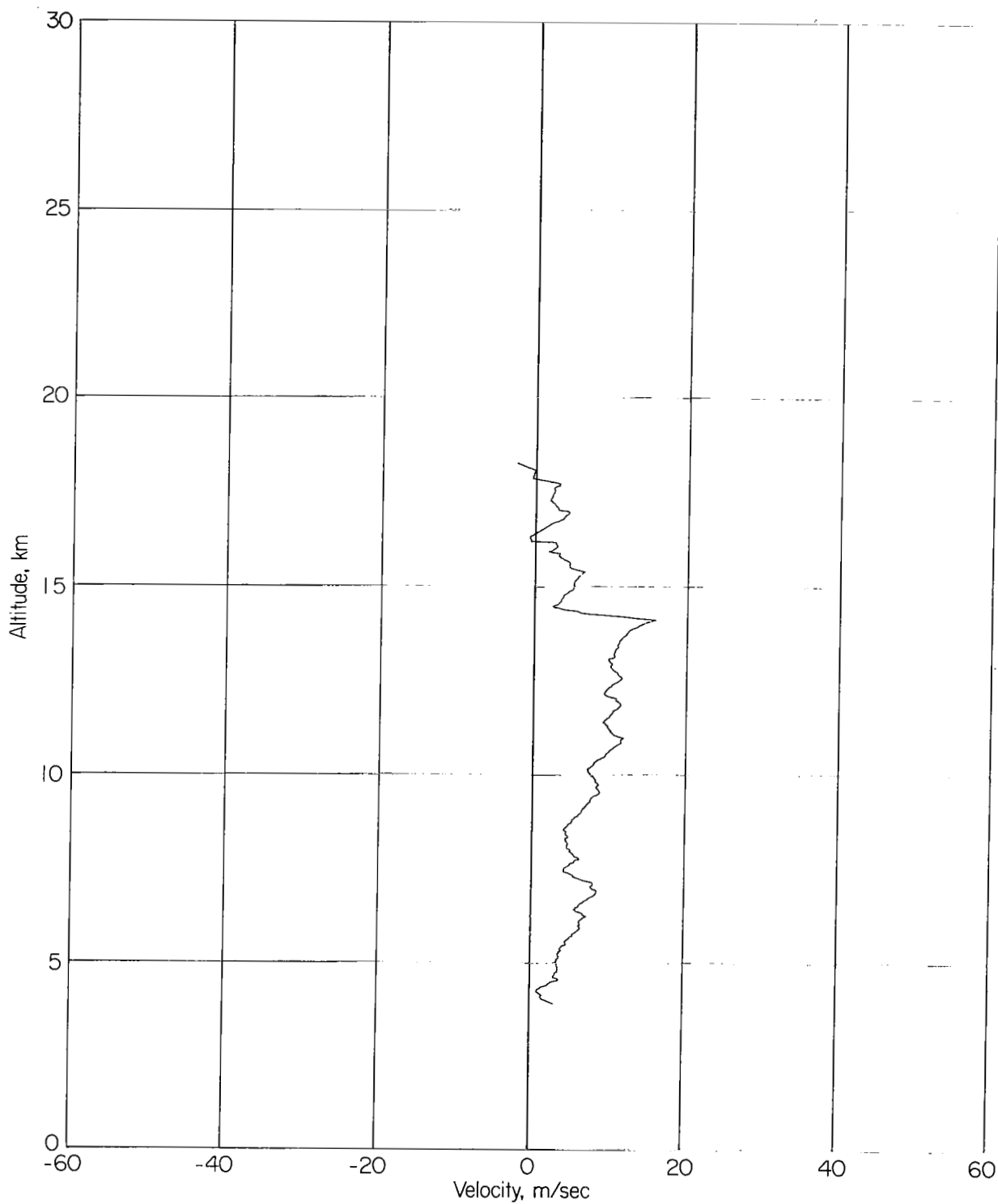
Figure 16.- Wind profile of smoke trail 395 obtained May 21, 1964.

Time interval, 60 seconds; height interval, 25 meters.



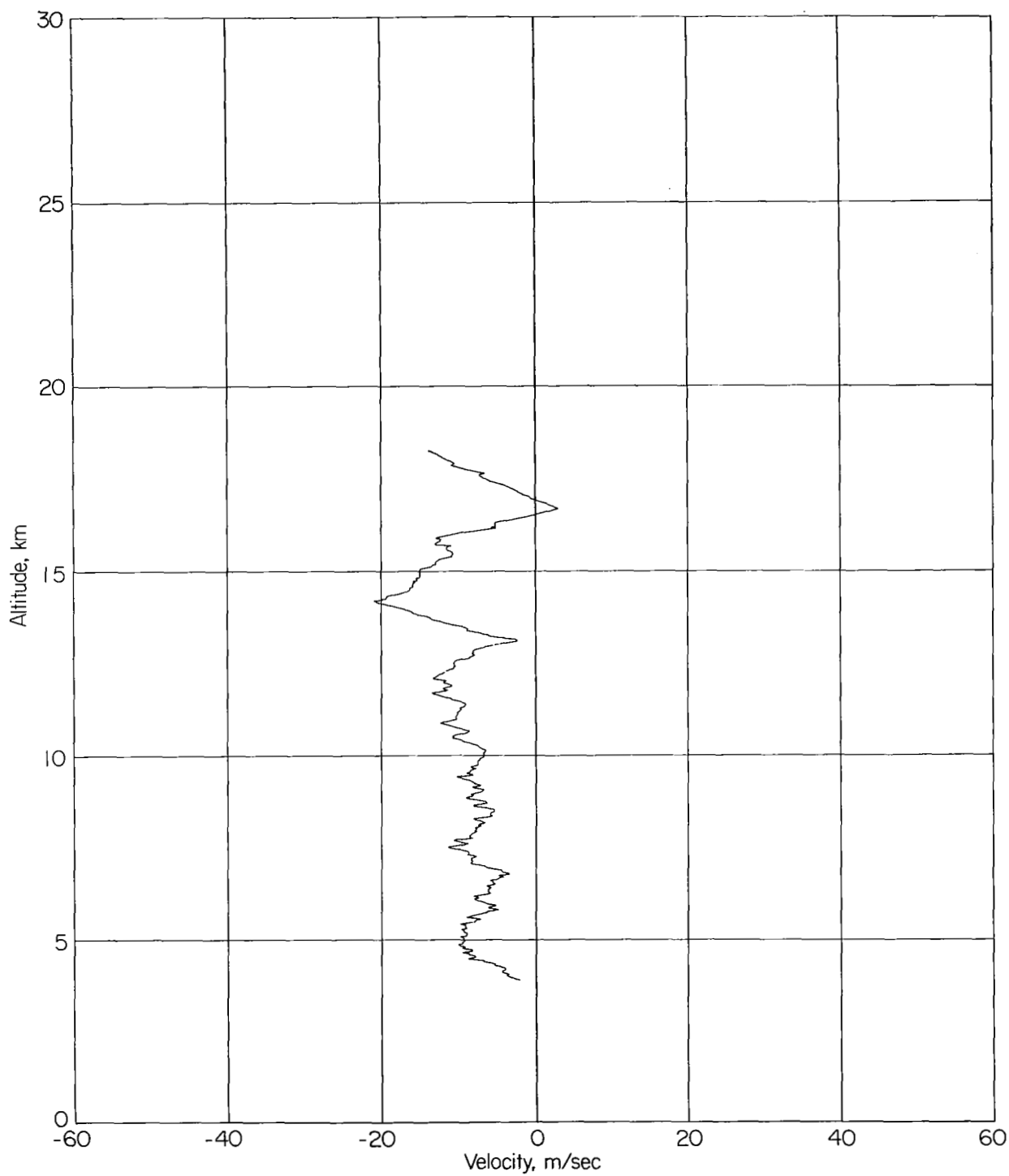
(b) South-to-north velocity component.

Figure 16.- Concluded.



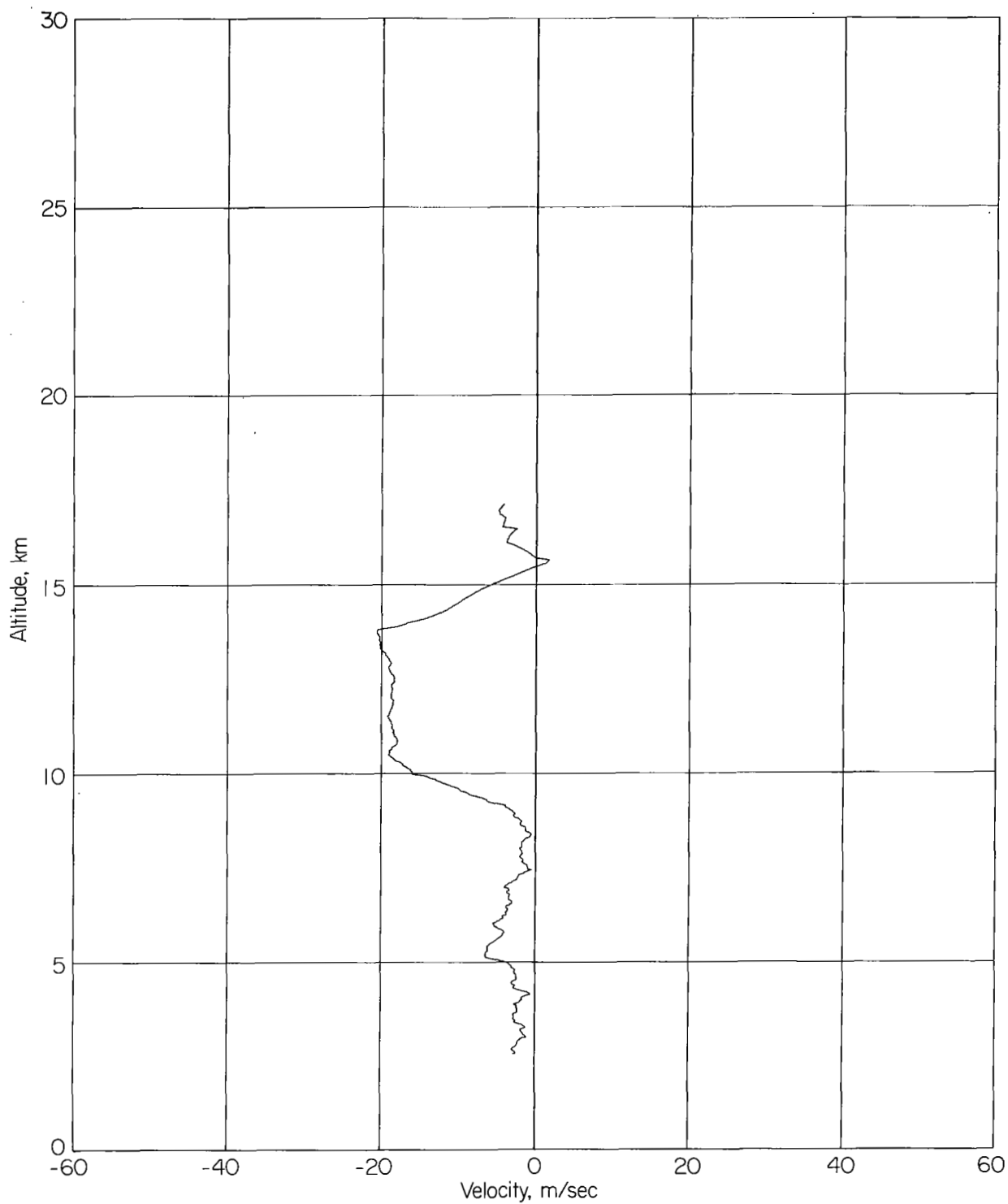
(a) West-to-east velocity component.

Figure 17.- Wind profile of smoke trail 396 obtained May 25, 1964.
Time interval, 60 seconds; height interval, 25 meters.



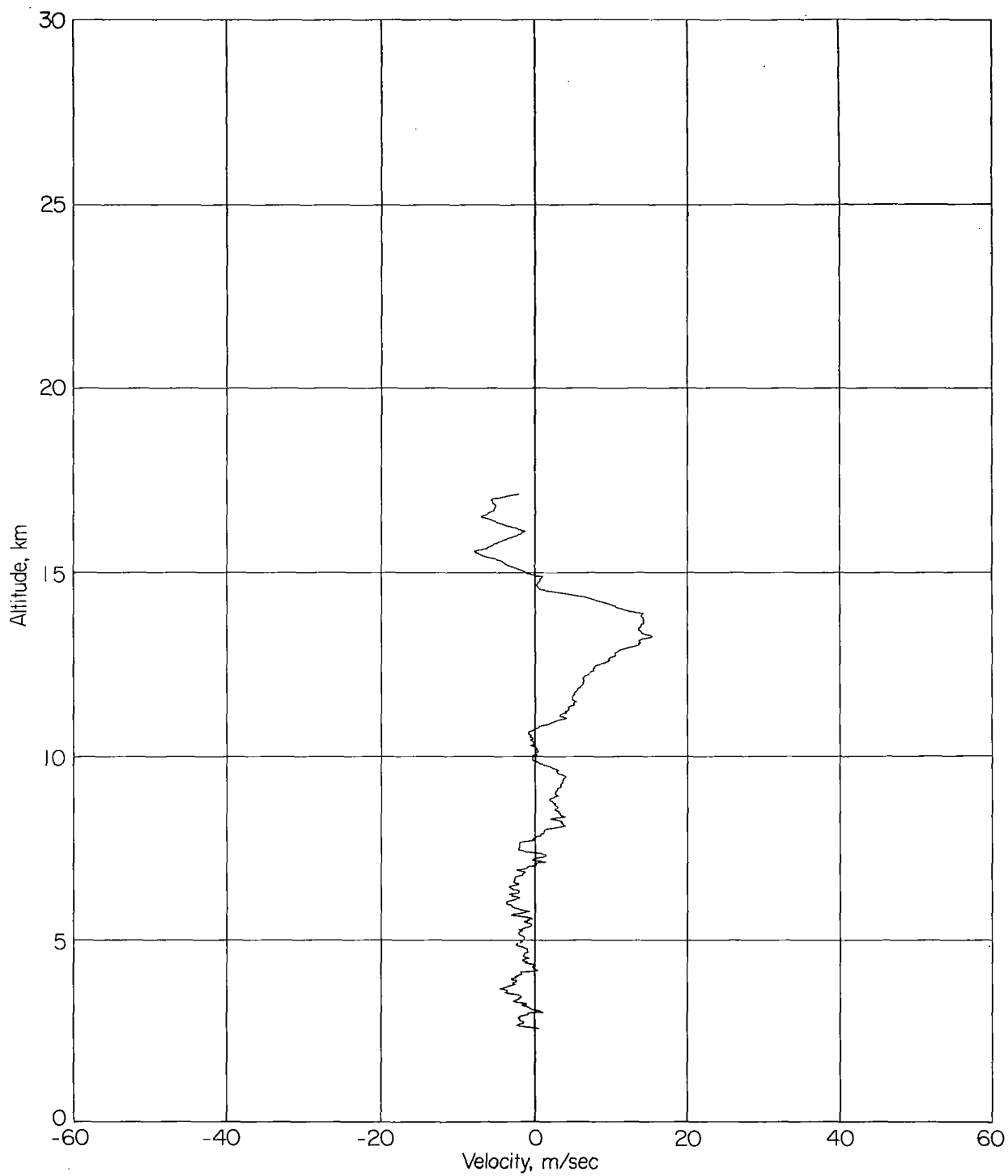
(b) South-to-north velocity component.

Figure 17.- Concluded.



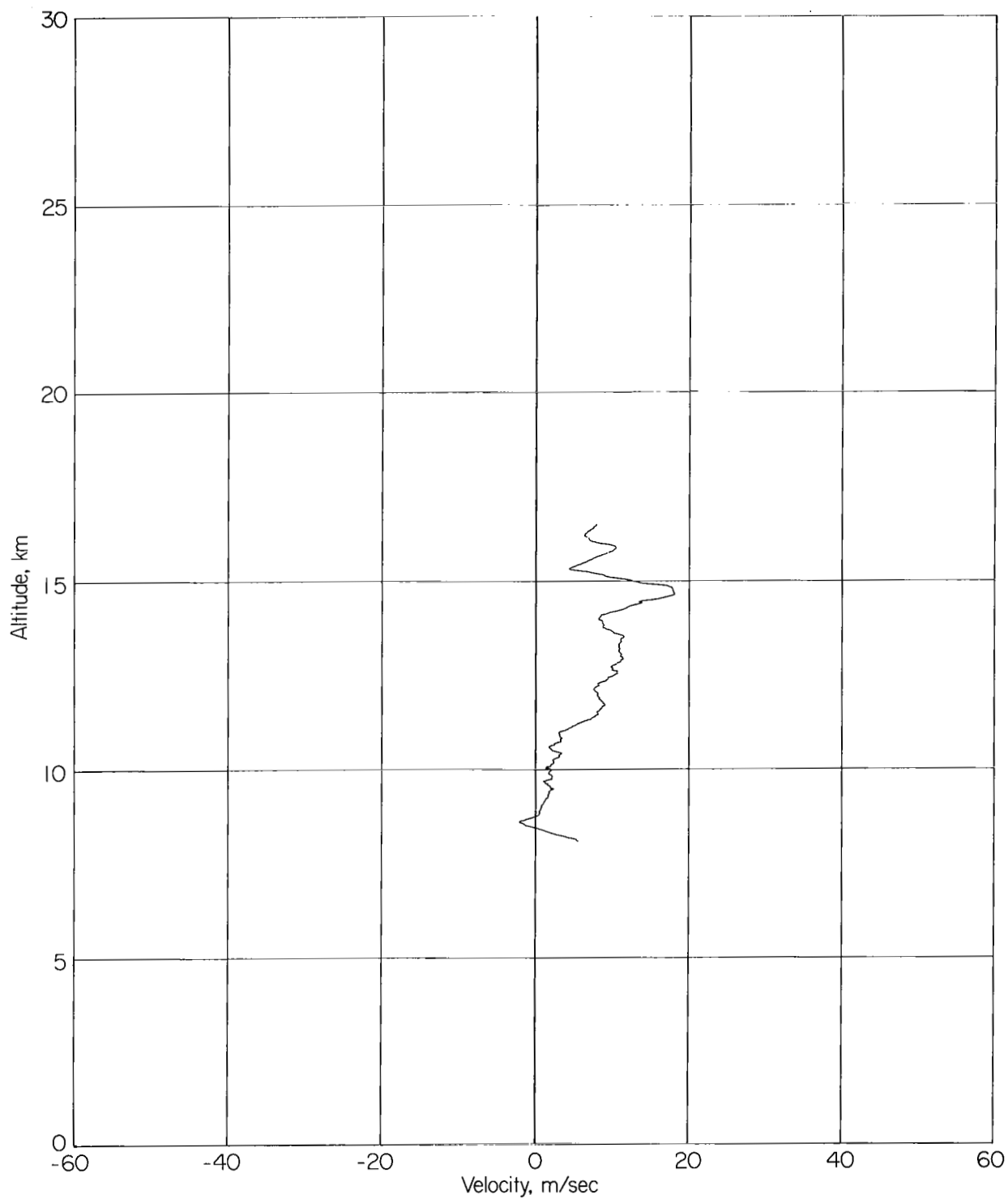
(a) West-to-east velocity component.

Figure 18.- Wind profile of smoke trail 397 obtained May 27, 1964.
Time interval, 60 seconds; height interval, 25 meters.



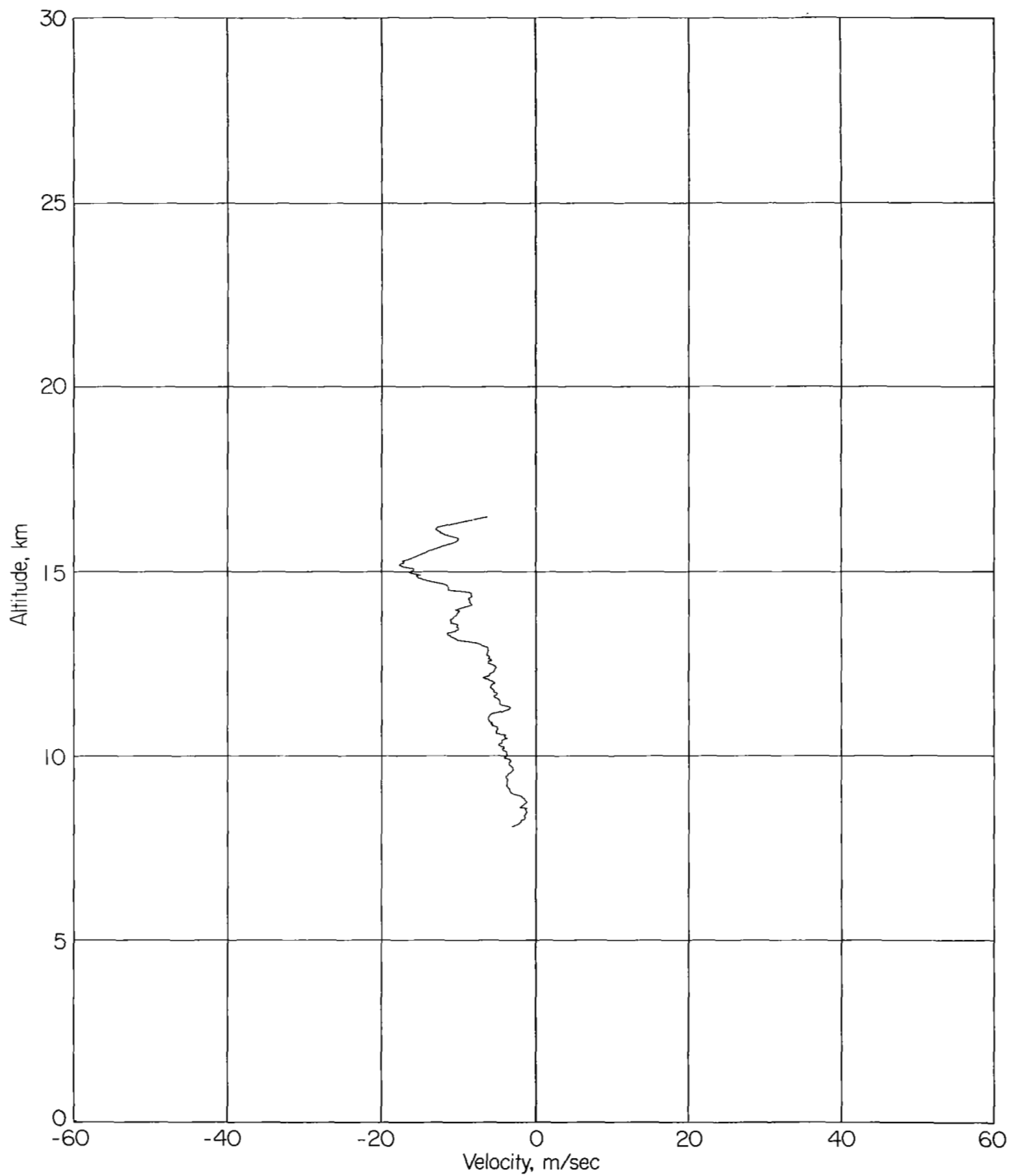
(b) South-to-north velocity component.

Figure 18.- Concluded.



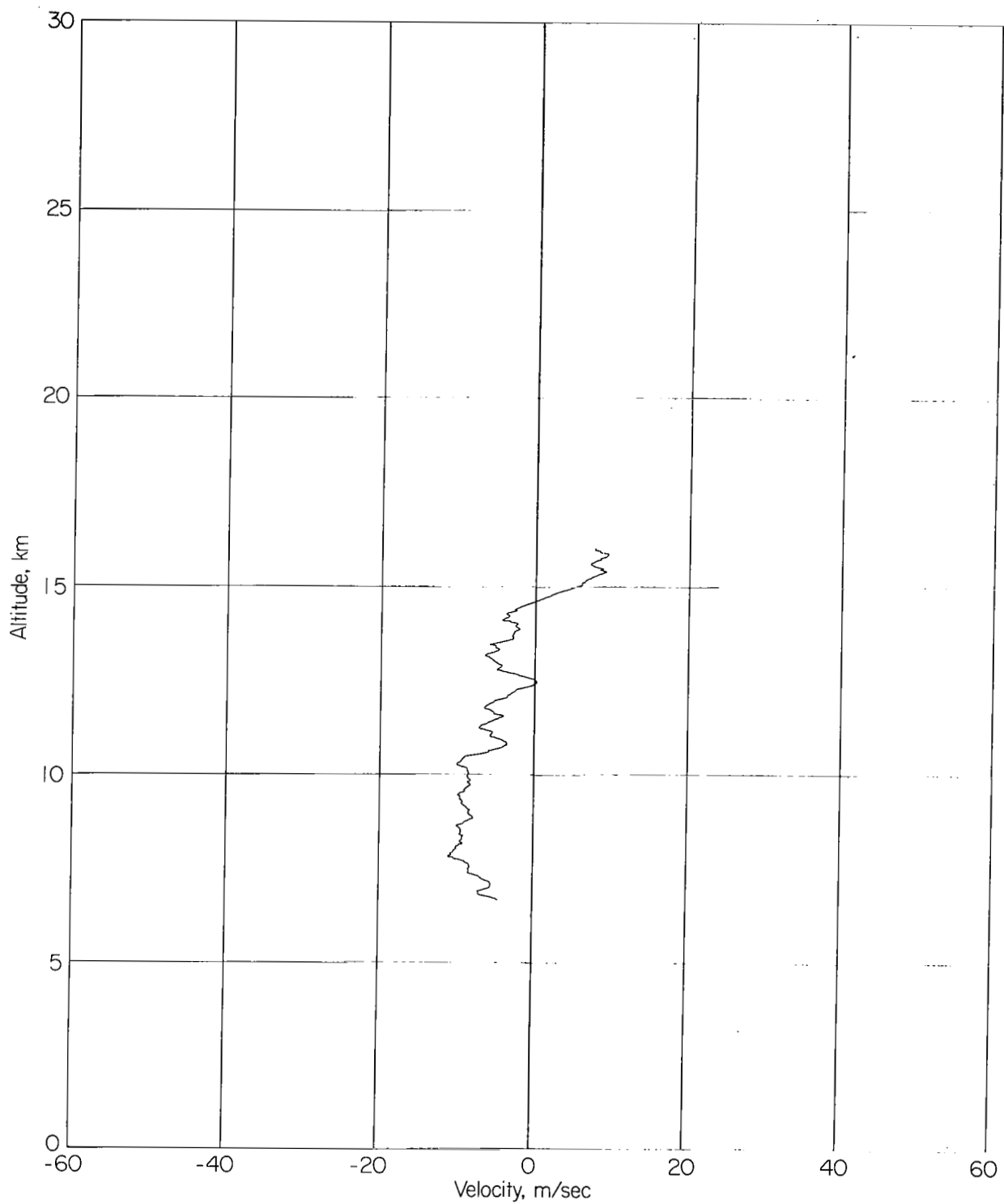
(a) West-to-east velocity component.

Figure 19.- Wind profile of smoke trail 398 obtained June 9, 1964.
Time interval, 60 seconds; height interval, 25 meters.



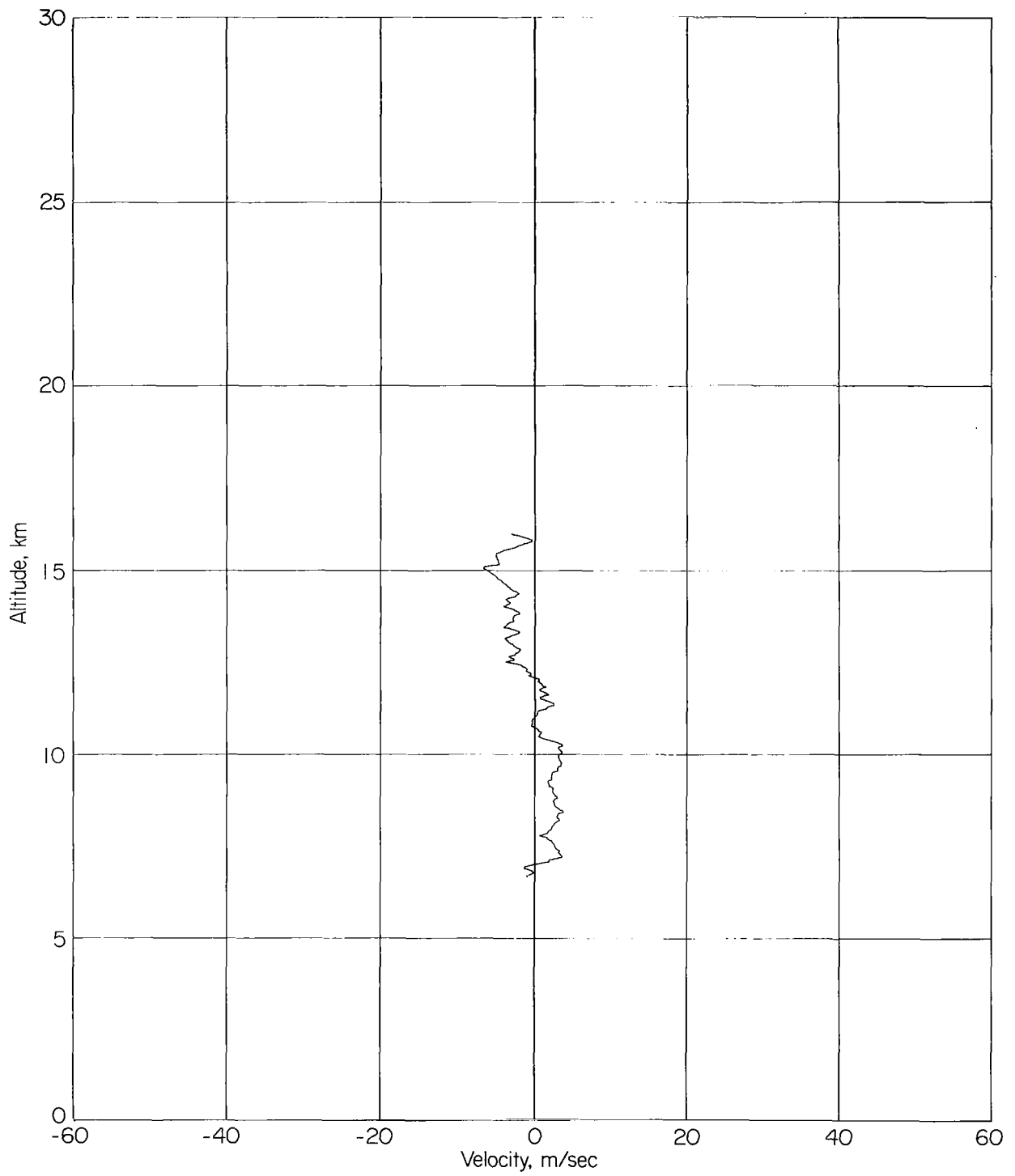
(b) South-to-north velocity component.

Figure 19.- Concluded.



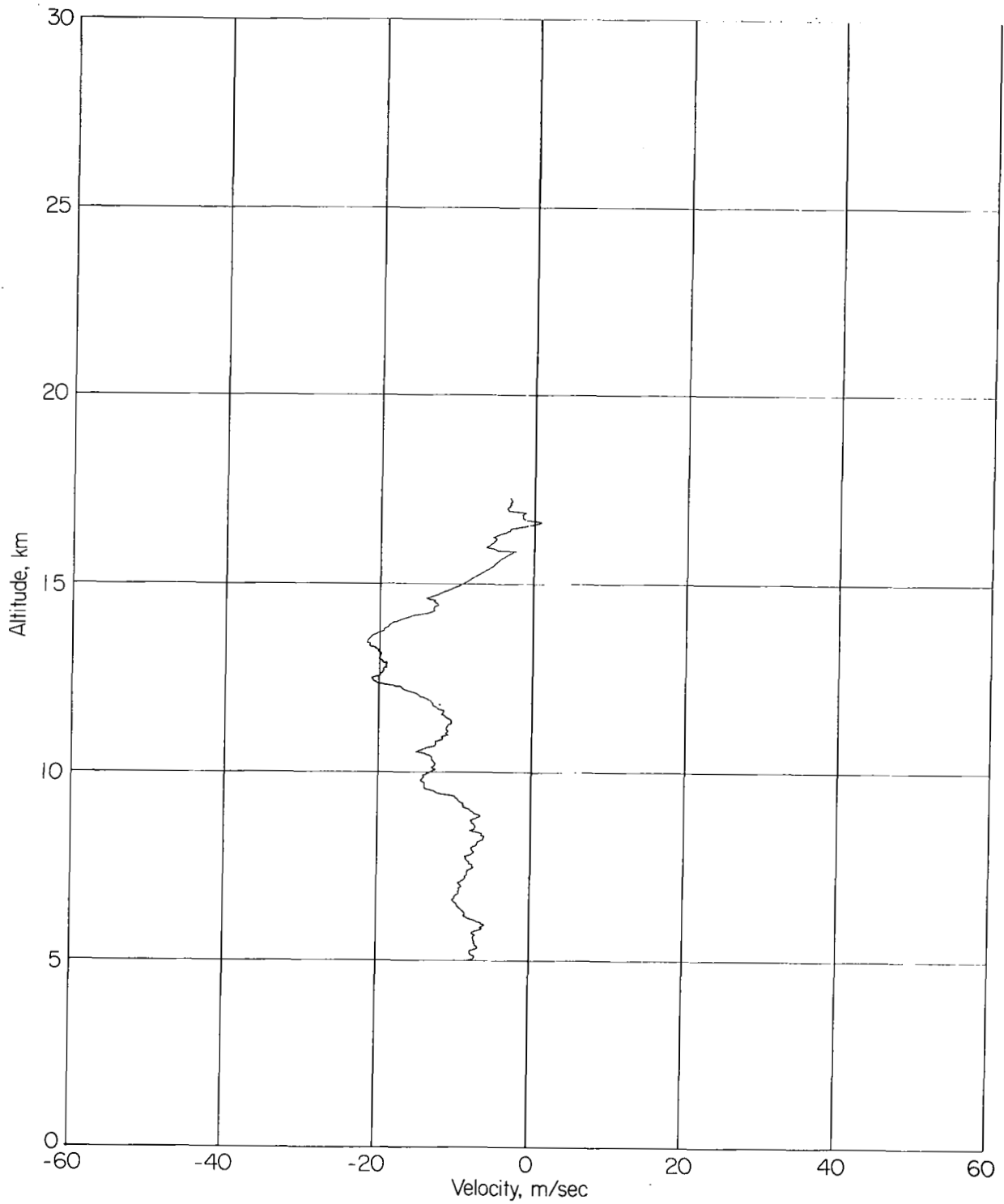
(a) West-to-east velocity component.

Figure 20.- Wind profile of smoke trail 399 obtained June 10, 1964.
Time interval, 60 seconds; height interval, 25 meters.



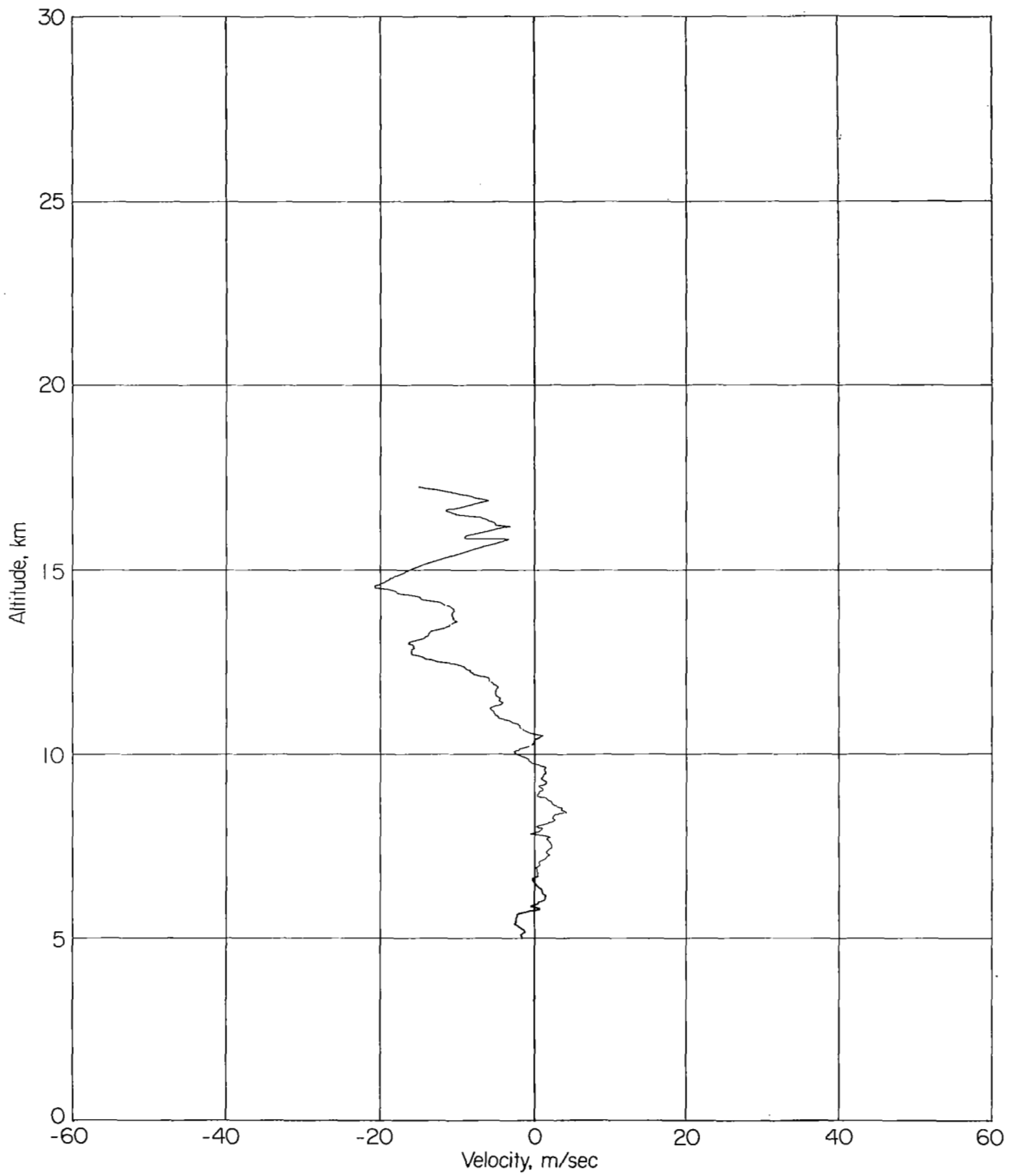
(b) South-to-north velocity component.

Figure 20.- Concluded.



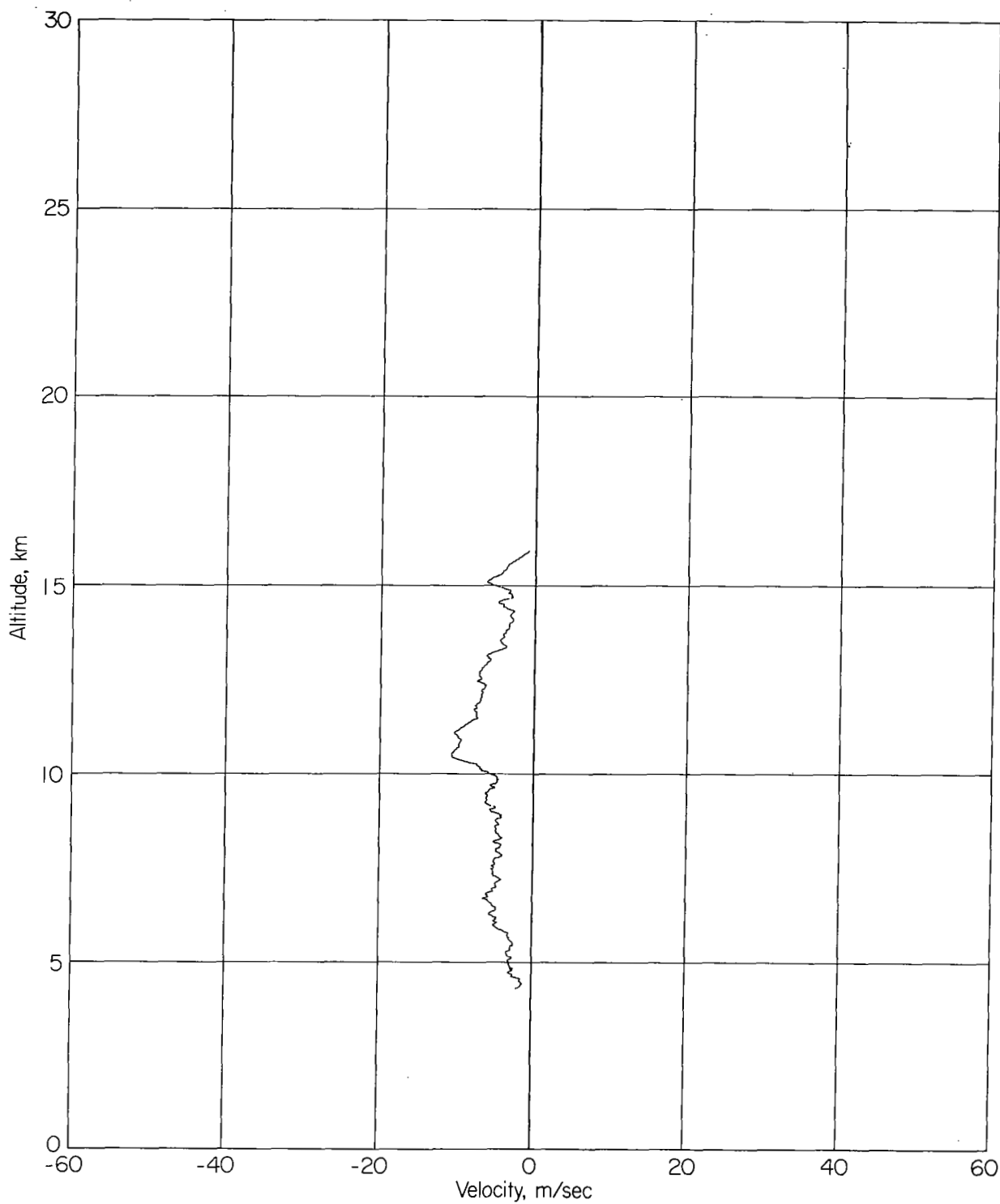
(a) West-to-east velocity component.

Figure 21.- Wind profile of smoke trail 400 obtained June 12, 1964.
Time interval, 60 seconds; height interval, 25 meters.



(b) South-to-north velocity component.

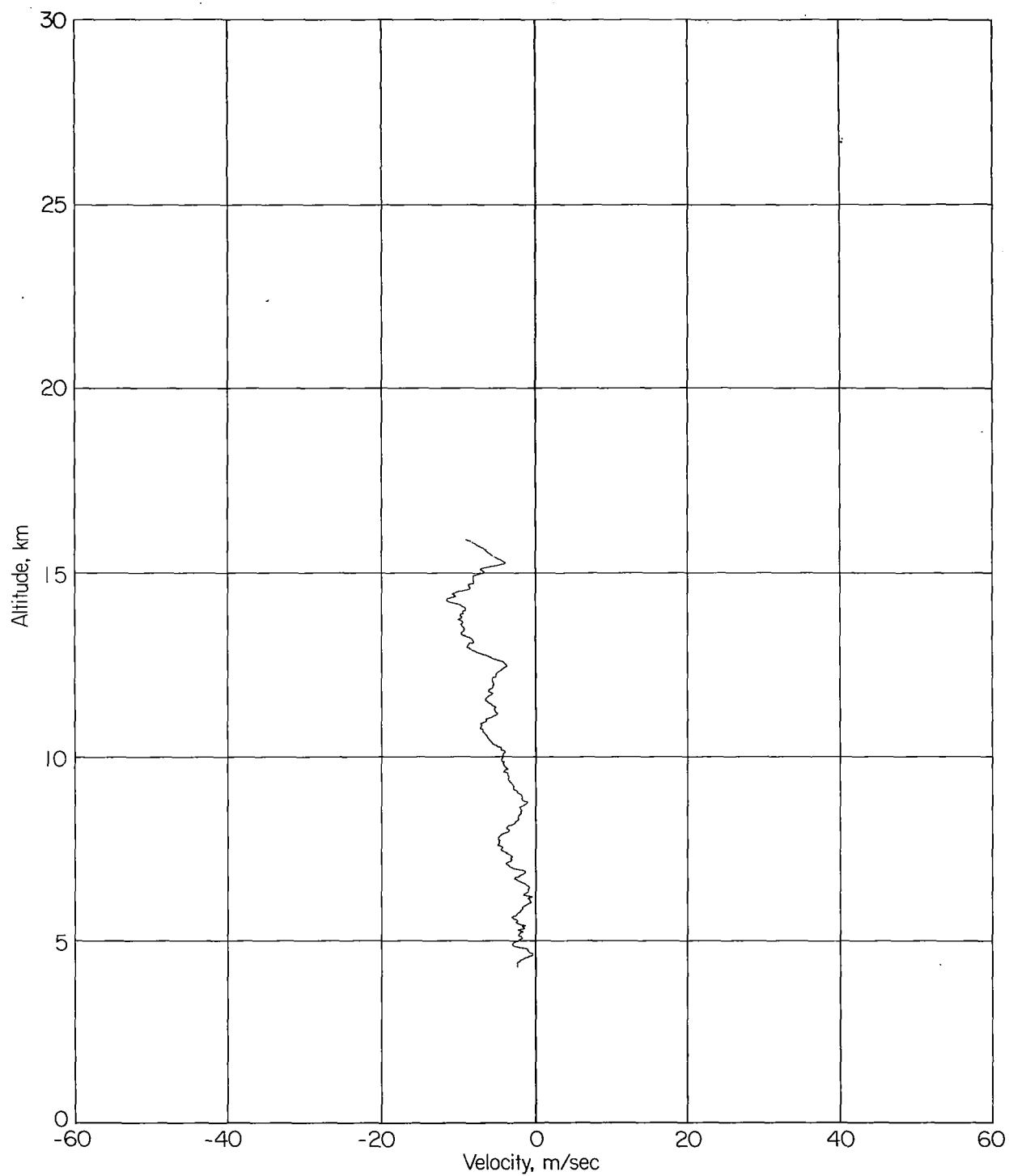
Figure 21.- Concluded.



(a) West-to-east velocity component.

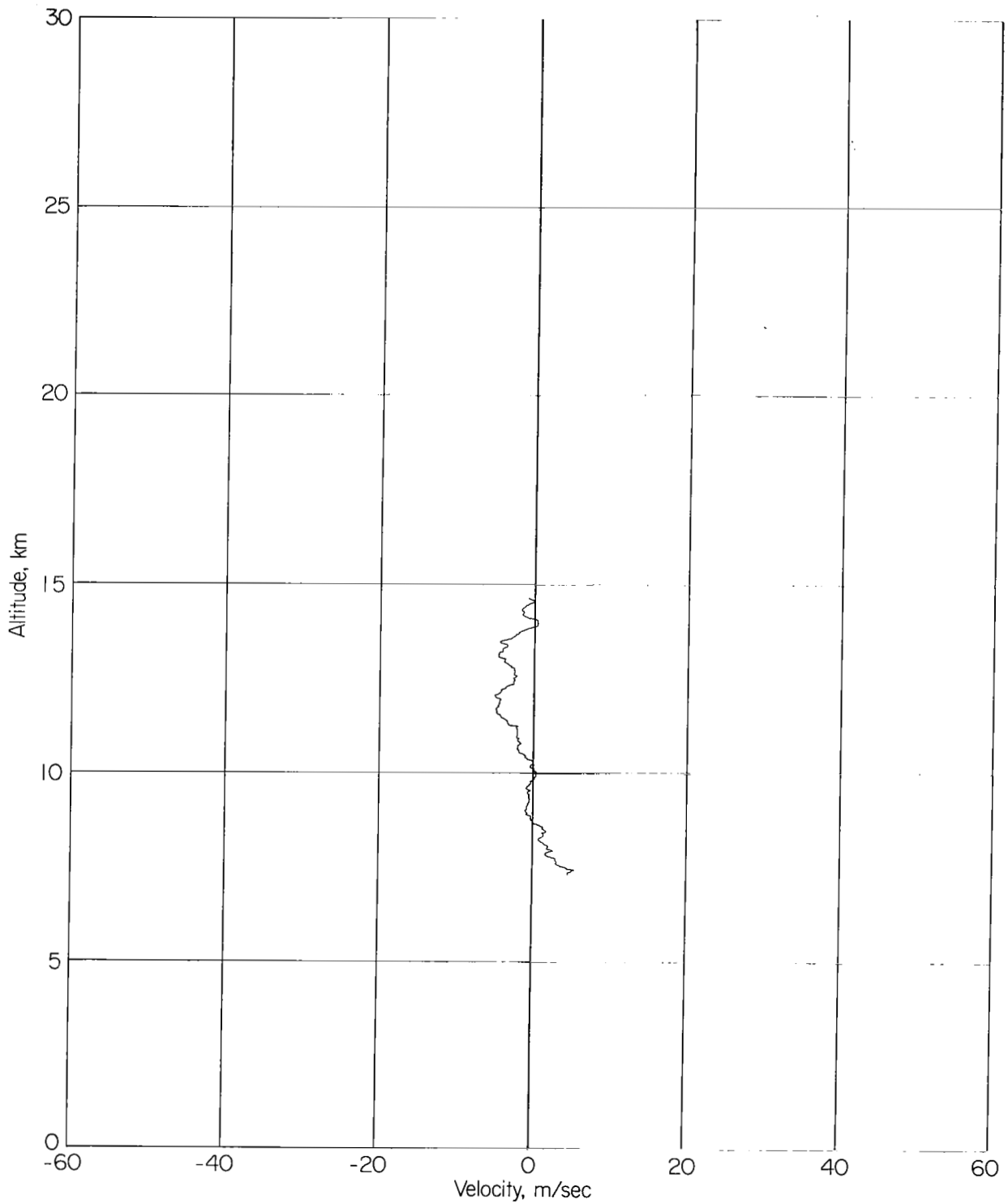
Figure 22.- Wind profile of smoke trail 401 obtained June 15, 1964.

Time interval, 60 seconds; height interval, 25 meters.



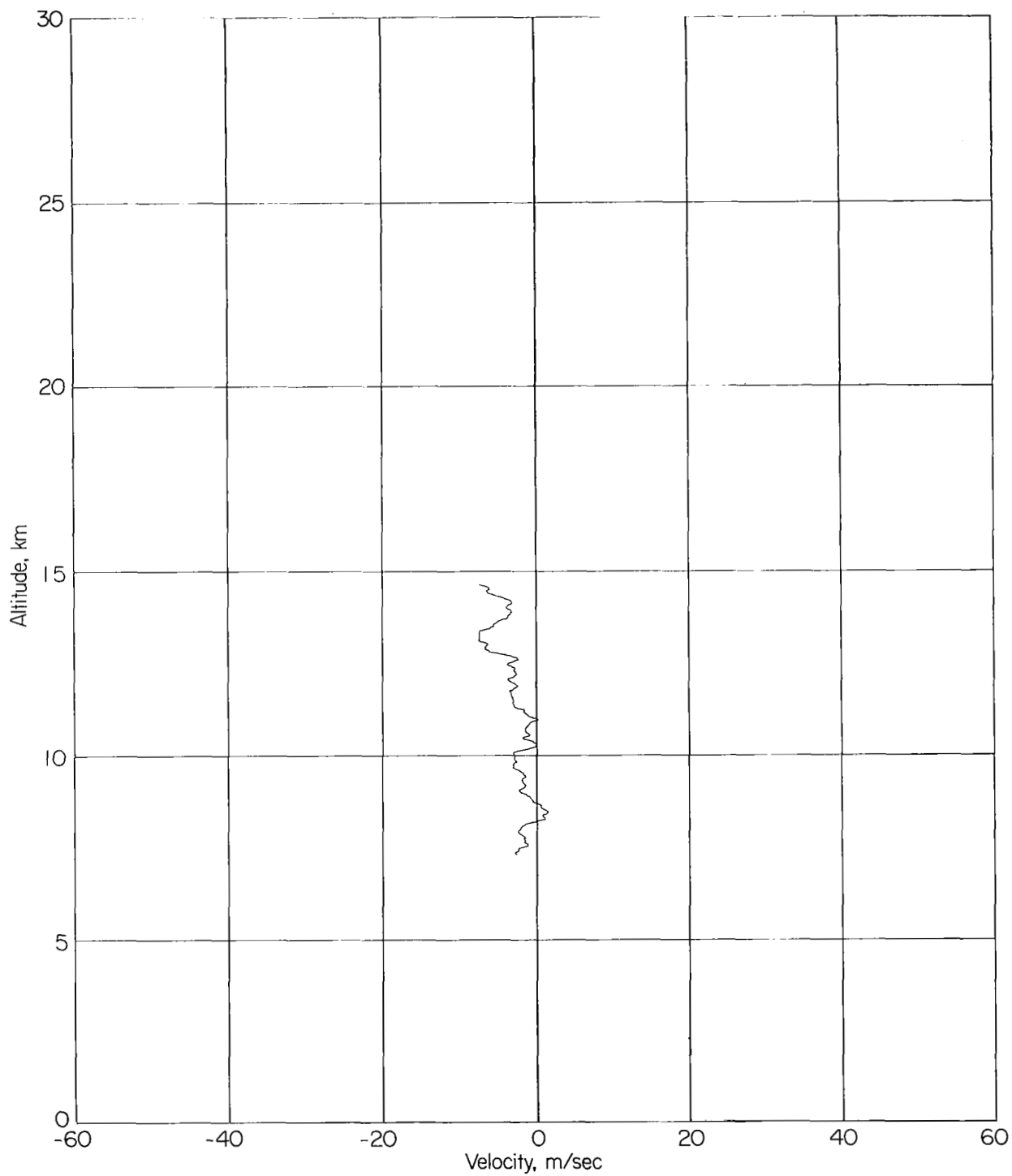
(b) South-to-north velocity component.

Figure 22.- Concluded.



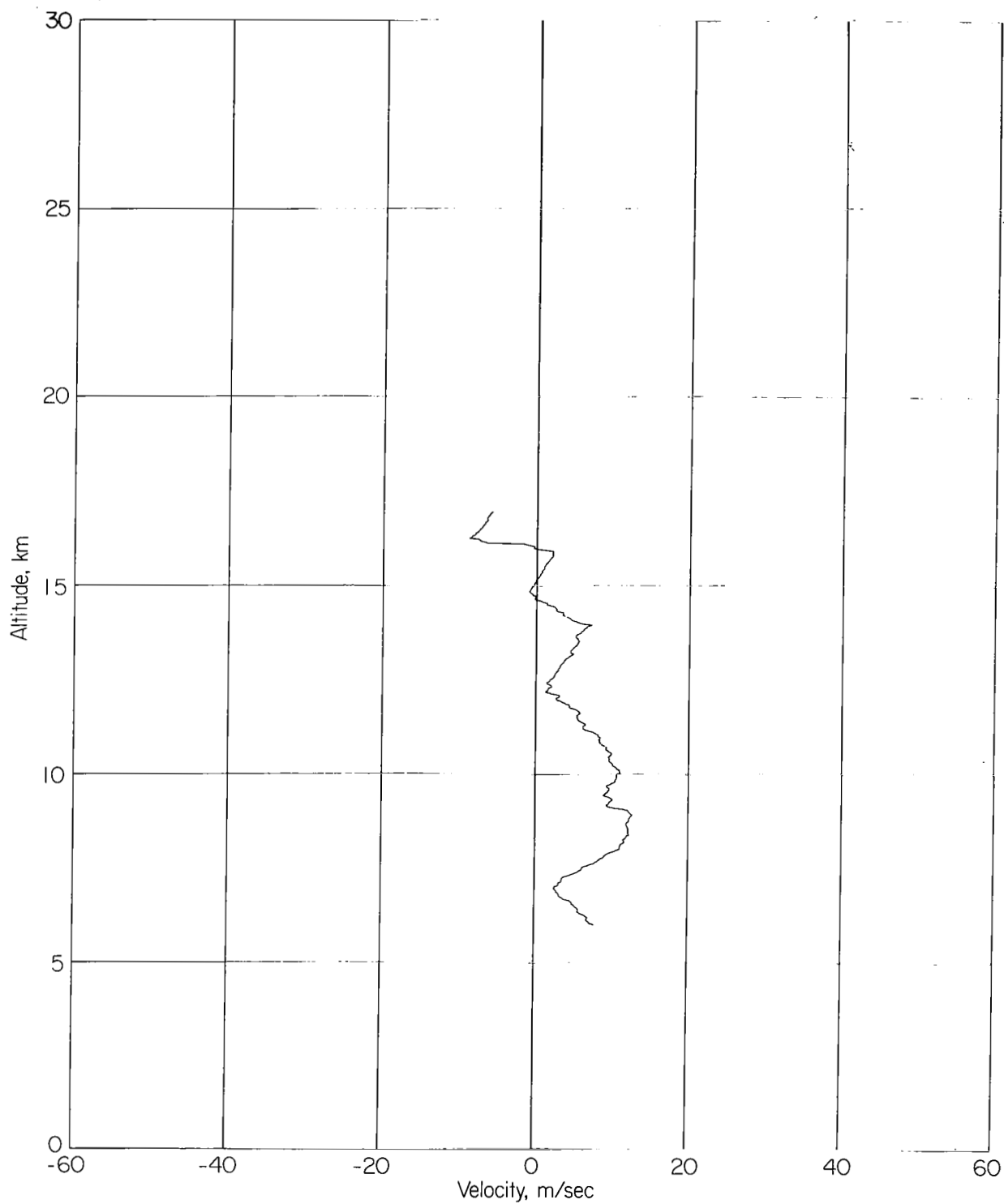
(a) West-to-east velocity component.

Figure 23.- Wind profile of smoke trail 402 obtained June 17, 1964.
Time interval, 60 seconds; height interval, 25 meters.



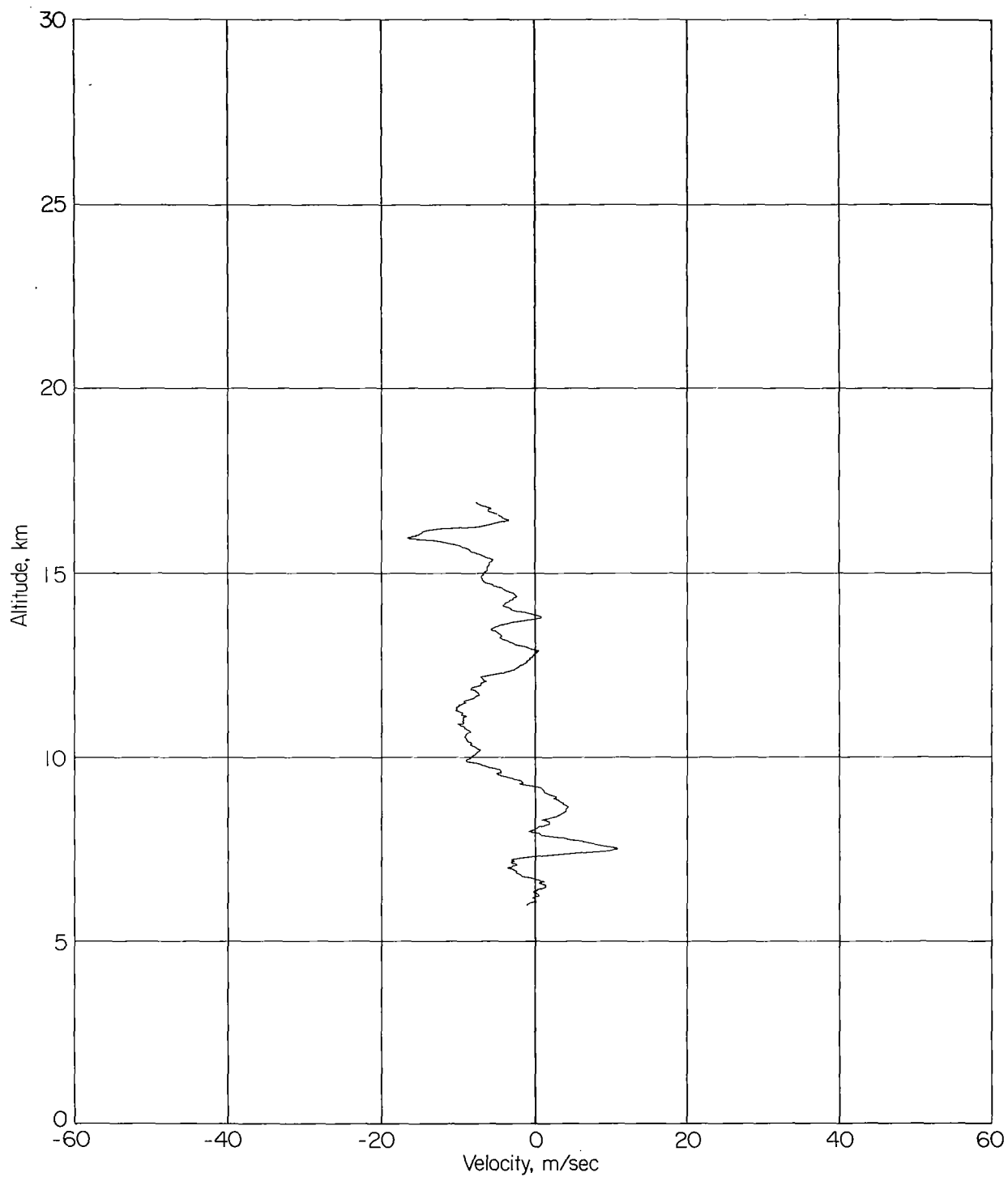
(b) South-to-north velocity component.

Figure 23.- Concluded.



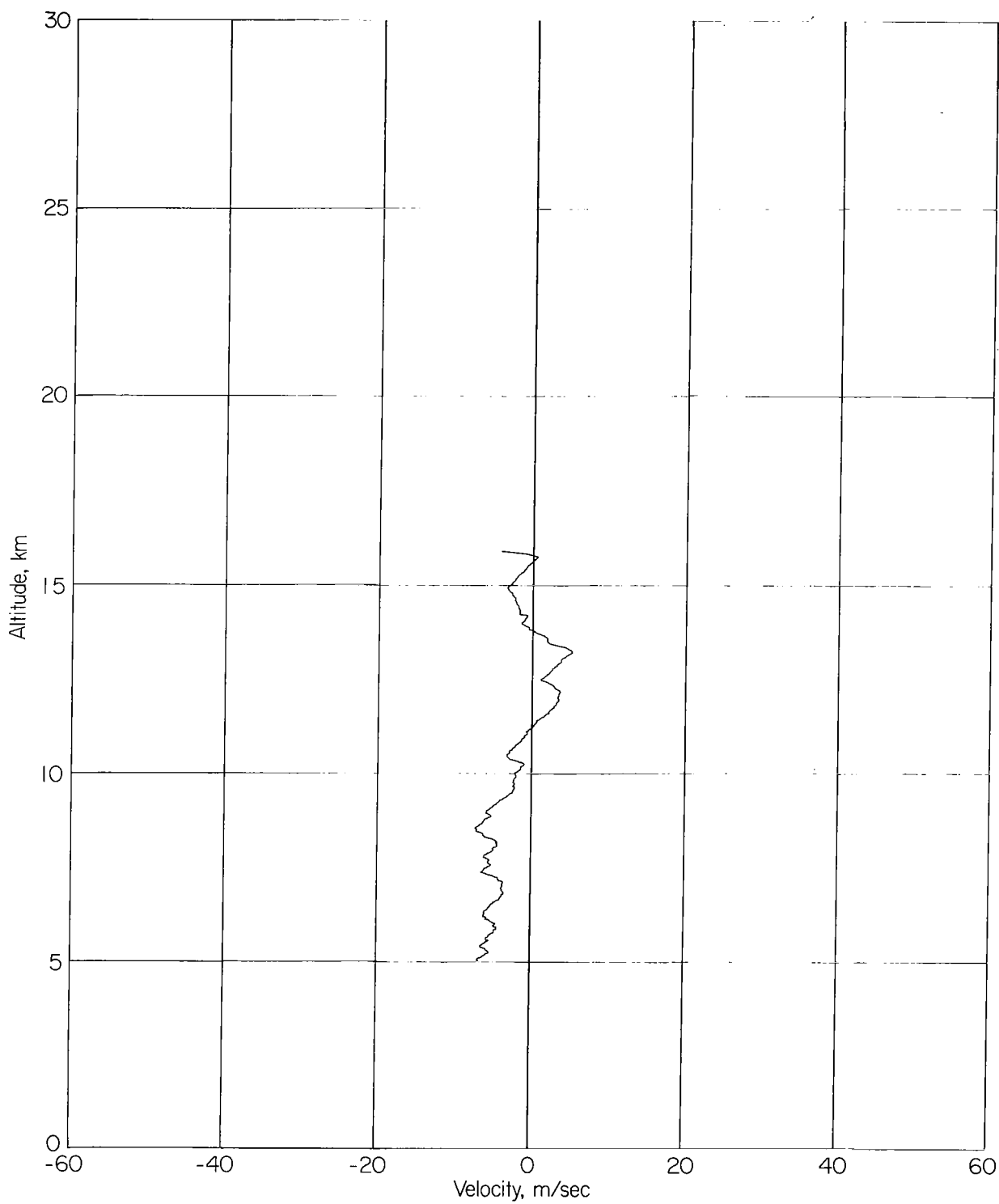
(a) West-to-east velocity component.

Figure 24.- Wind profile of smoke trail 403 obtained July 6, 1964.
Time interval, 60 seconds; height interval, 25 meters.



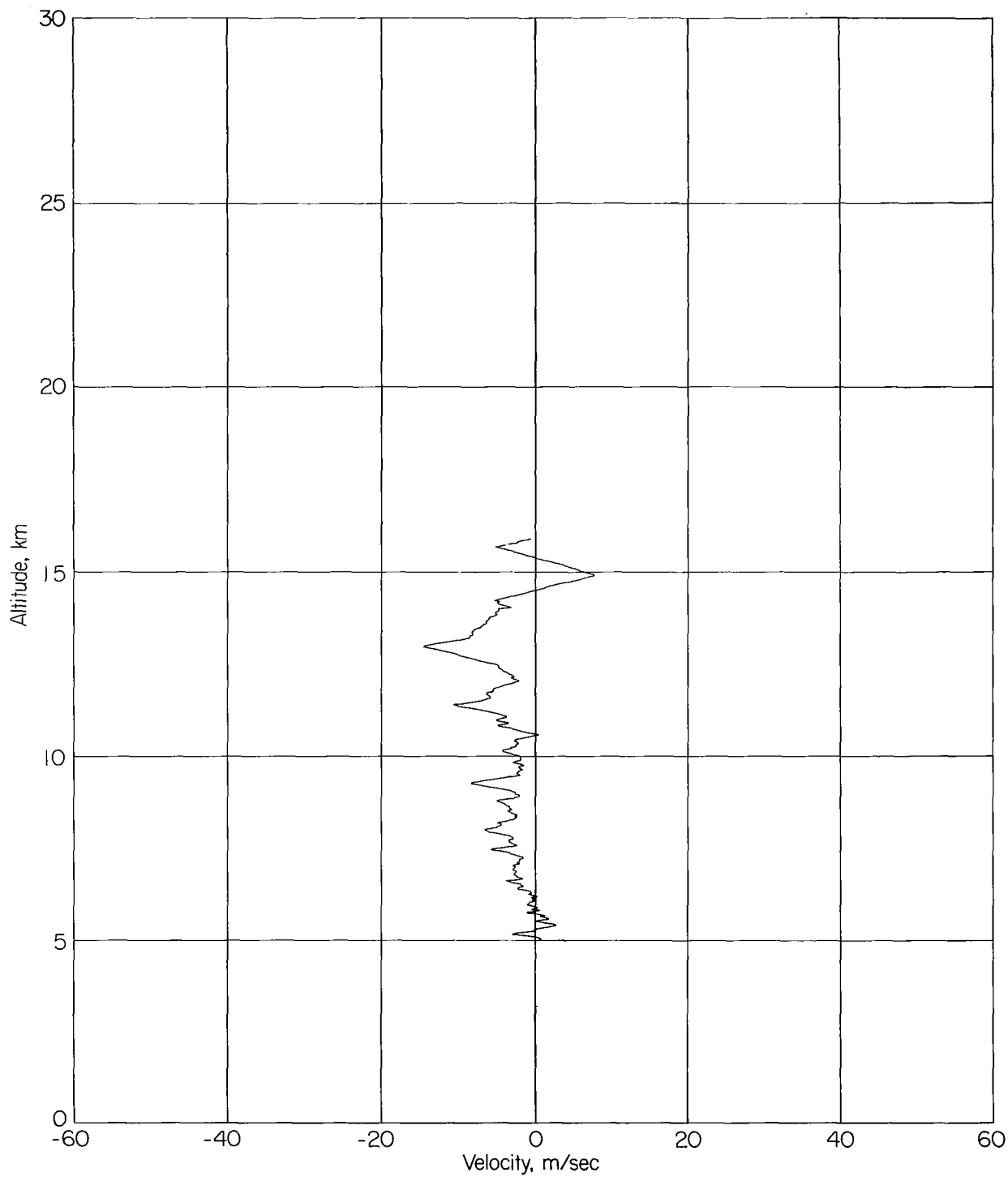
(b) South-to-north velocity component.

Figure 24.- Concluded.



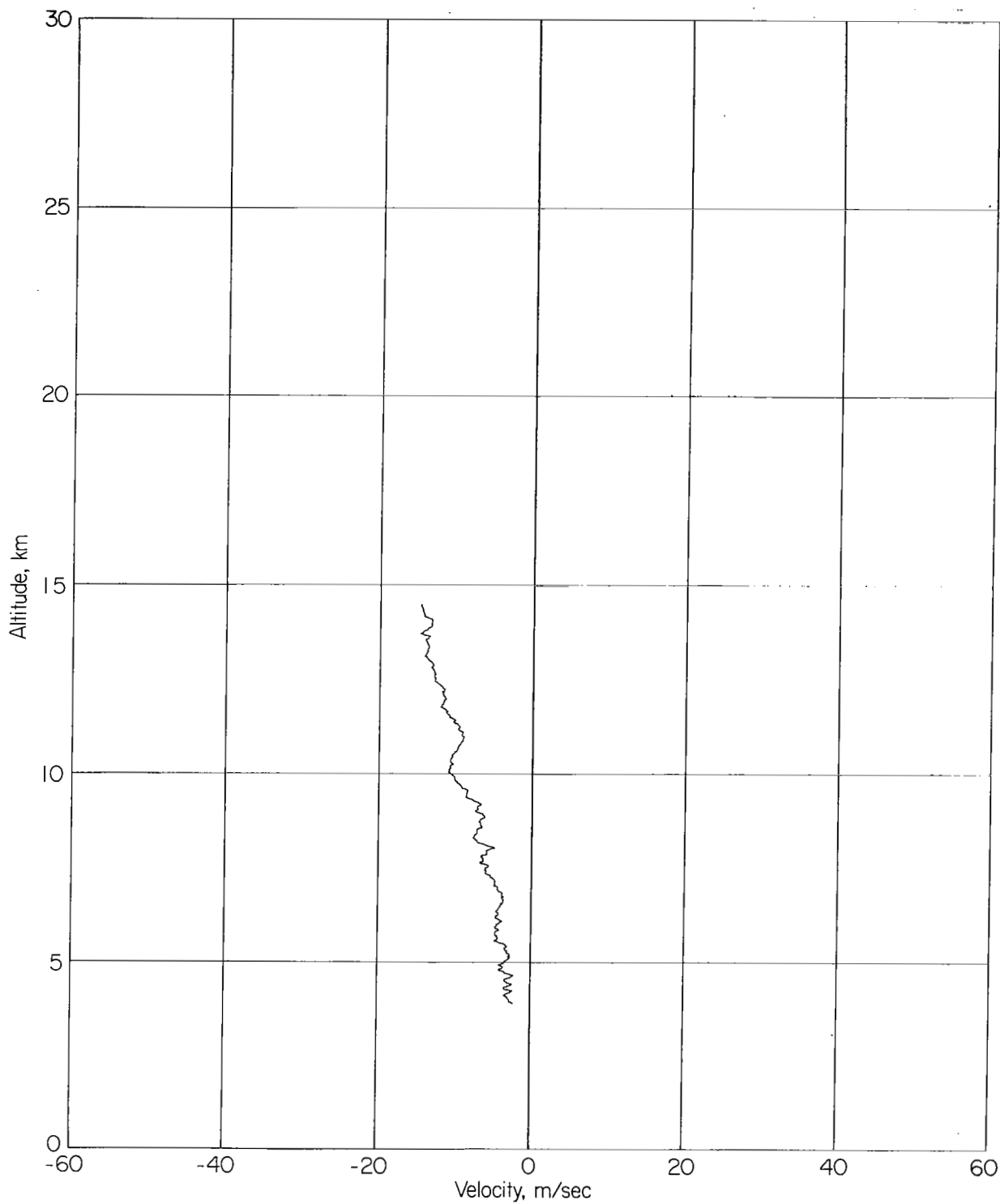
(a) West-to-east velocity component.

Figure 25.- Wind profile of smoke trail 404 obtained July 15, 1964.
Time interval, 60 seconds; height interval, 25 meters.



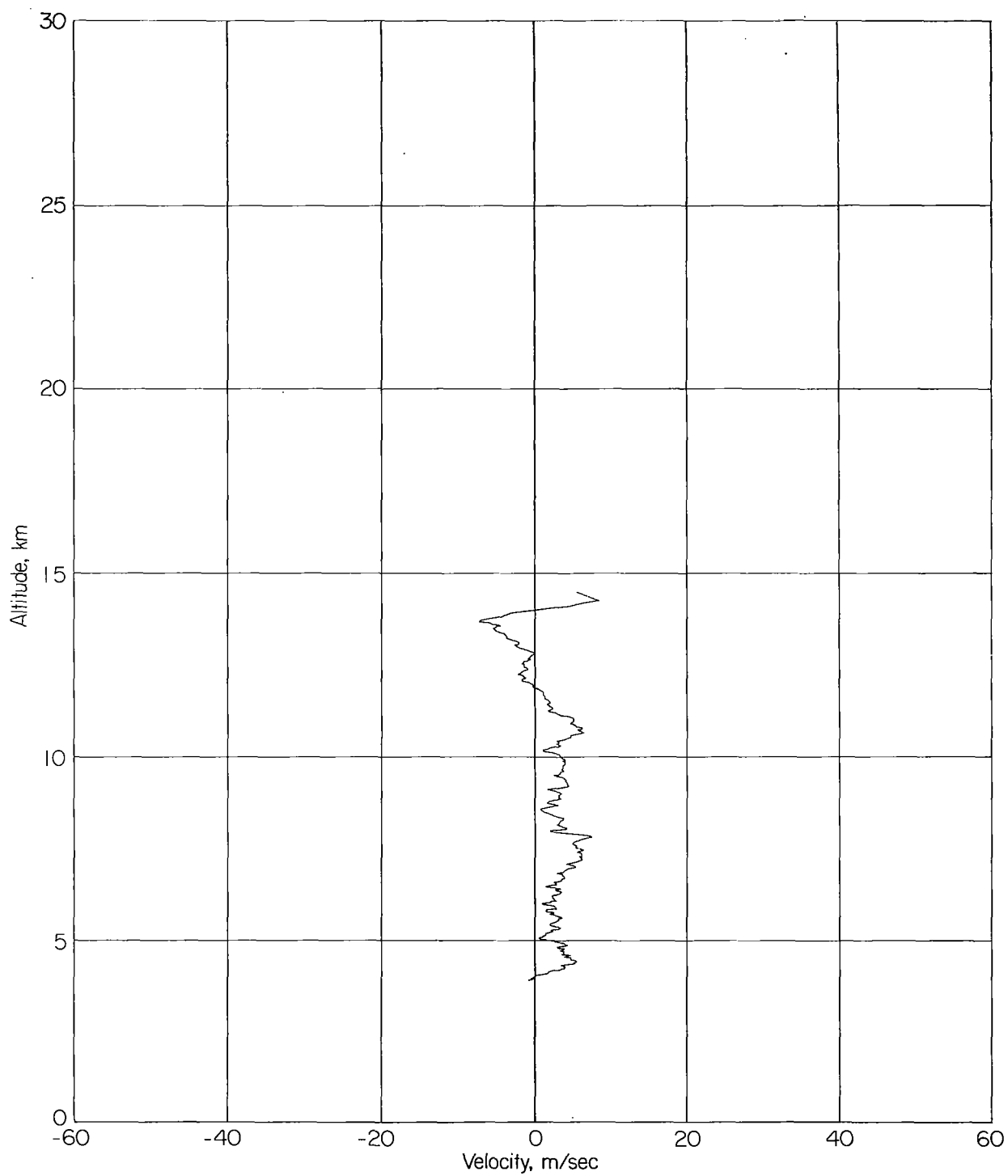
(b) South-to-north velocity component.

Figure 25.- Concluded.



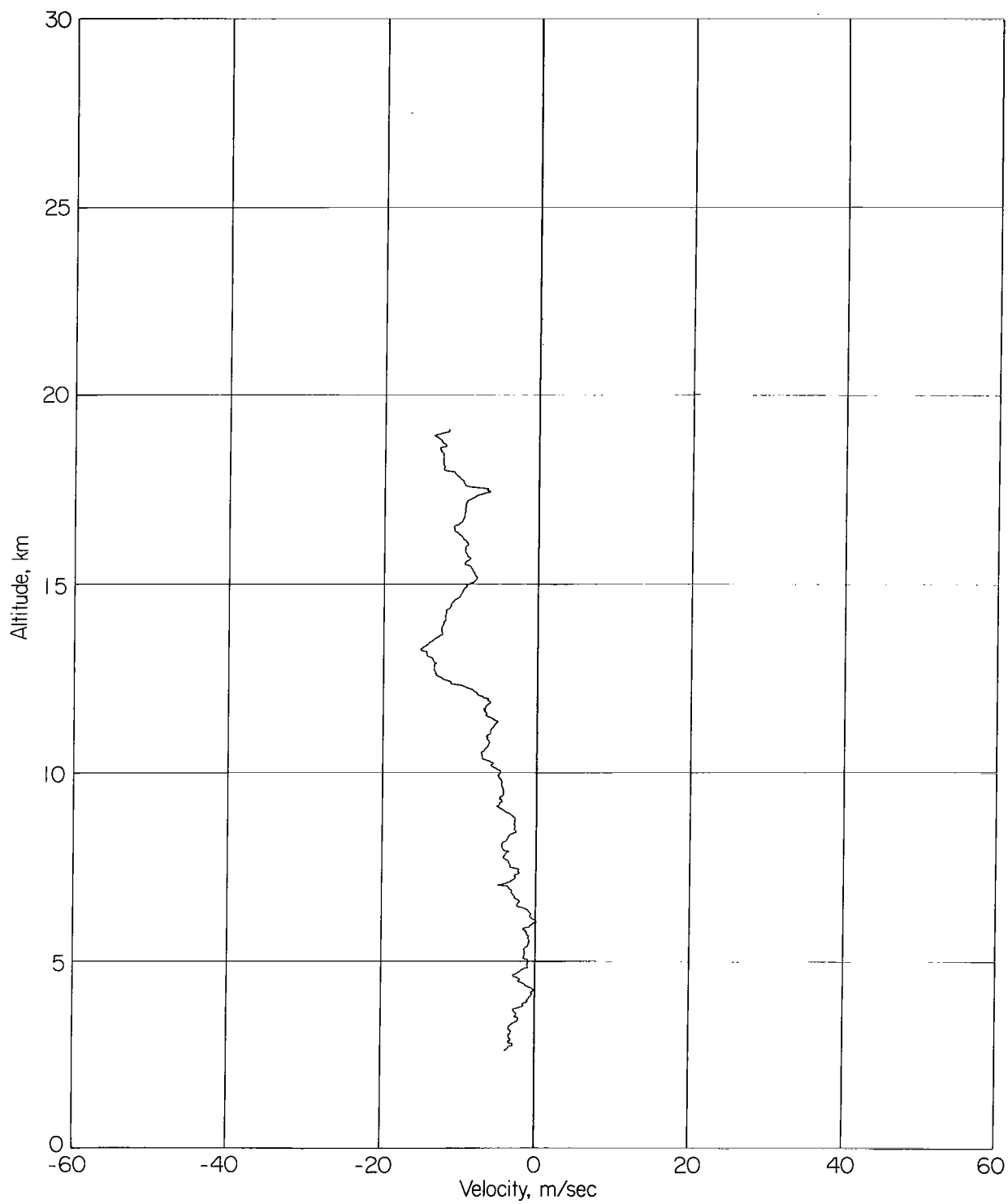
(a) West-to-east velocity component.

Figure 26.- Wind profile of smoke trail 405 obtained July 28, 1964.
Time interval, 60 seconds; height interval, 25 meters.



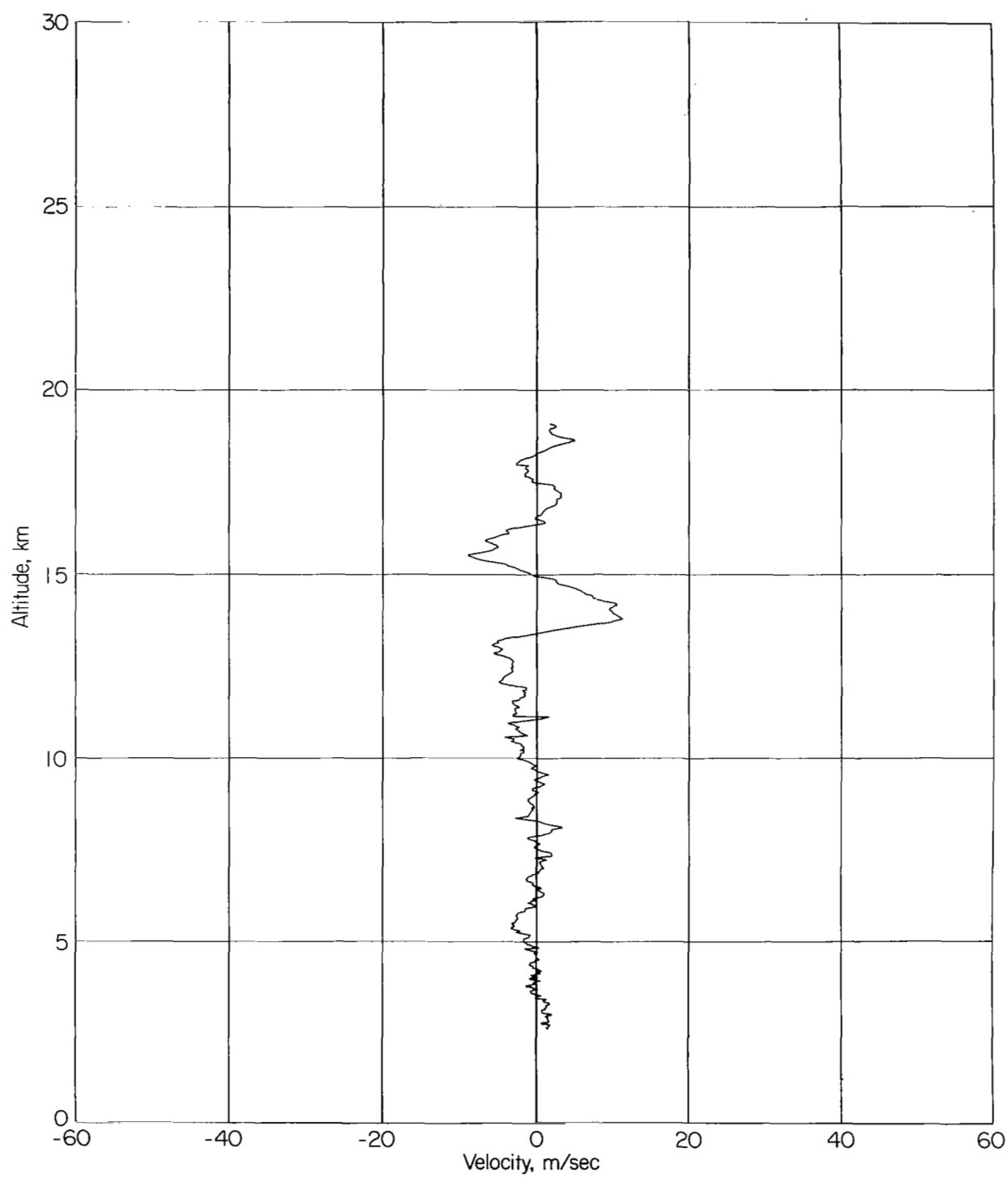
(b) South-to-north velocity component.

Figure 26.- Concluded.



(a) West-to-east velocity component.

Figure 27.- Wind profile of smoke trail 406 obtained July 29, 1964.
Time interval, 60 seconds; height interval, 25 meters.



(b) South-to-north velocity component.

Figure 27.- Concluded.

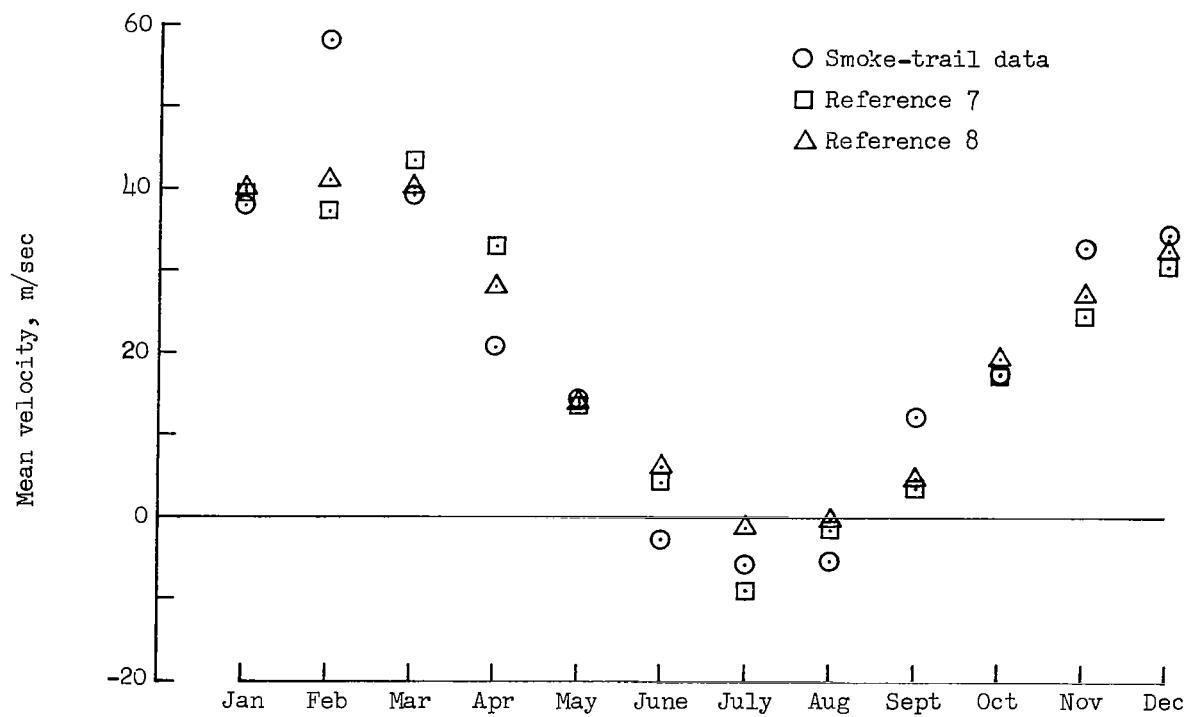


Figure 28.- Mean wind velocity of the zonal component measured at an altitude of 11 km at the Eastern Test Range.

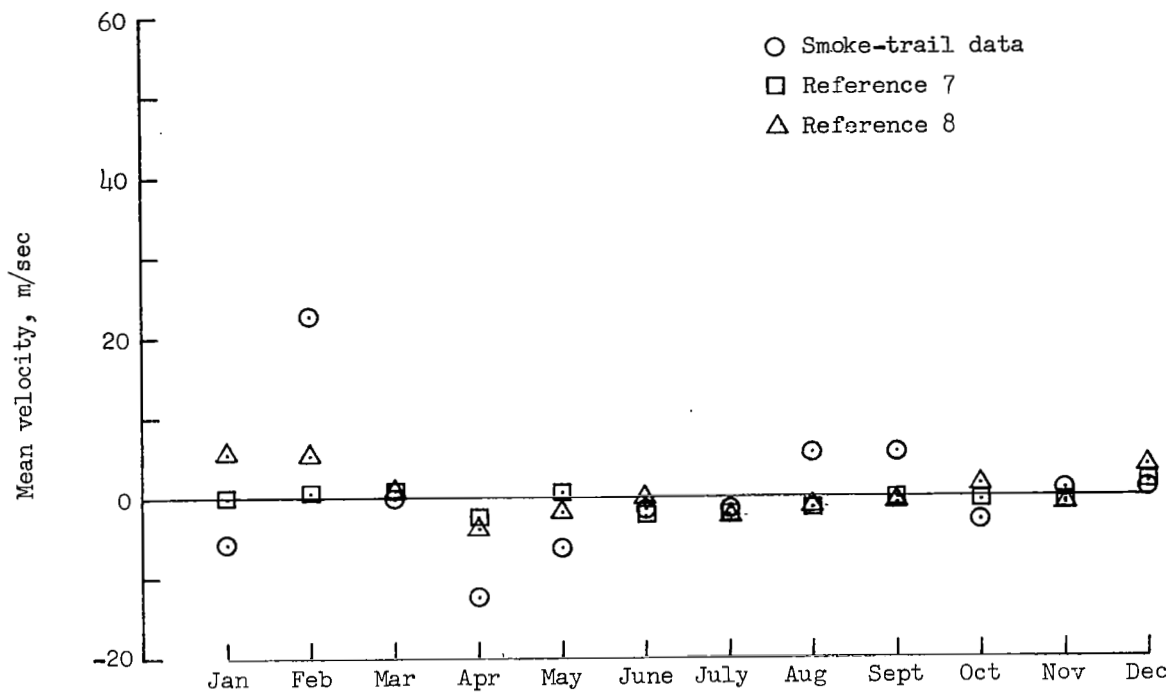


Figure 29.- Mean wind velocity of the meridional component measured at an altitude of 11 km at the Eastern Test Range.

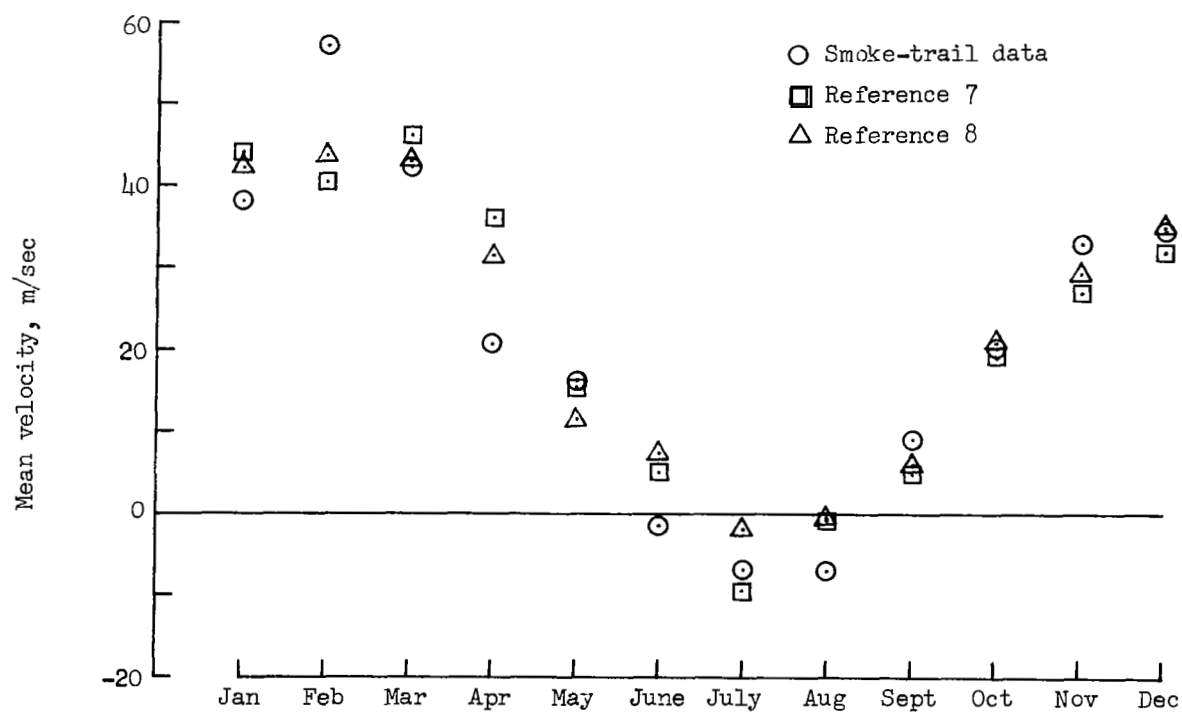


Figure 30.- Mean wind velocity of the zonal component measured at an altitude of 12 km at the Eastern Test Range.

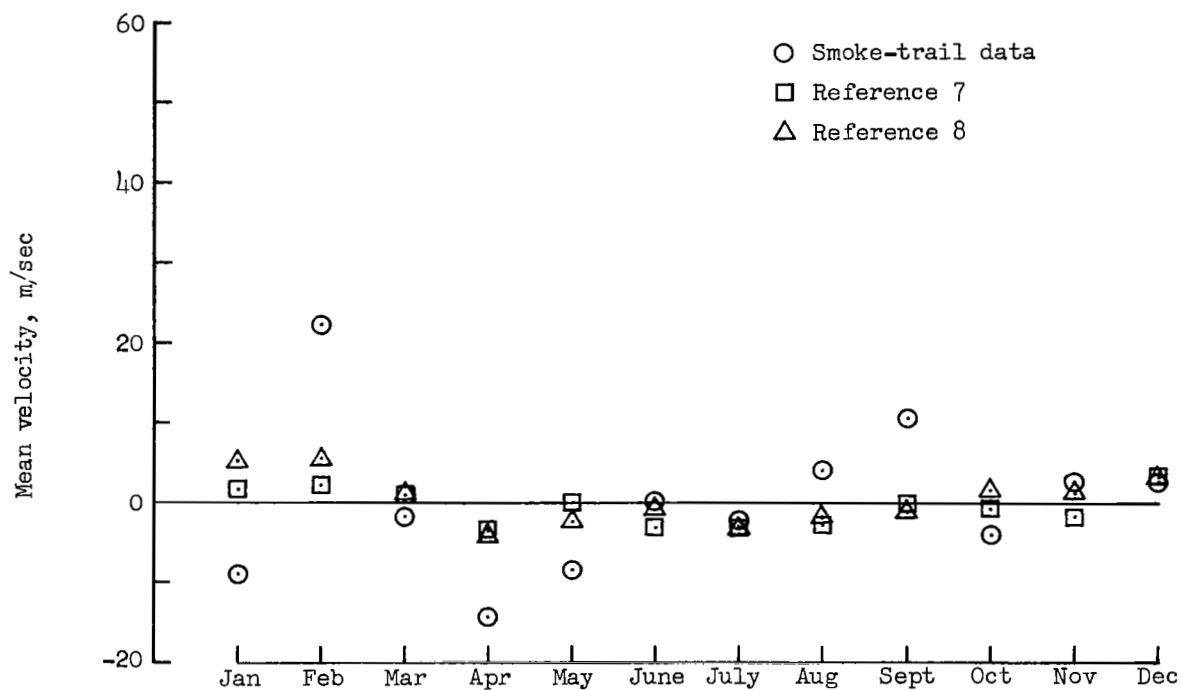


Figure 31.- Mean wind velocity of the meridional component measured at an altitude of 12 km at the Eastern Test Range.

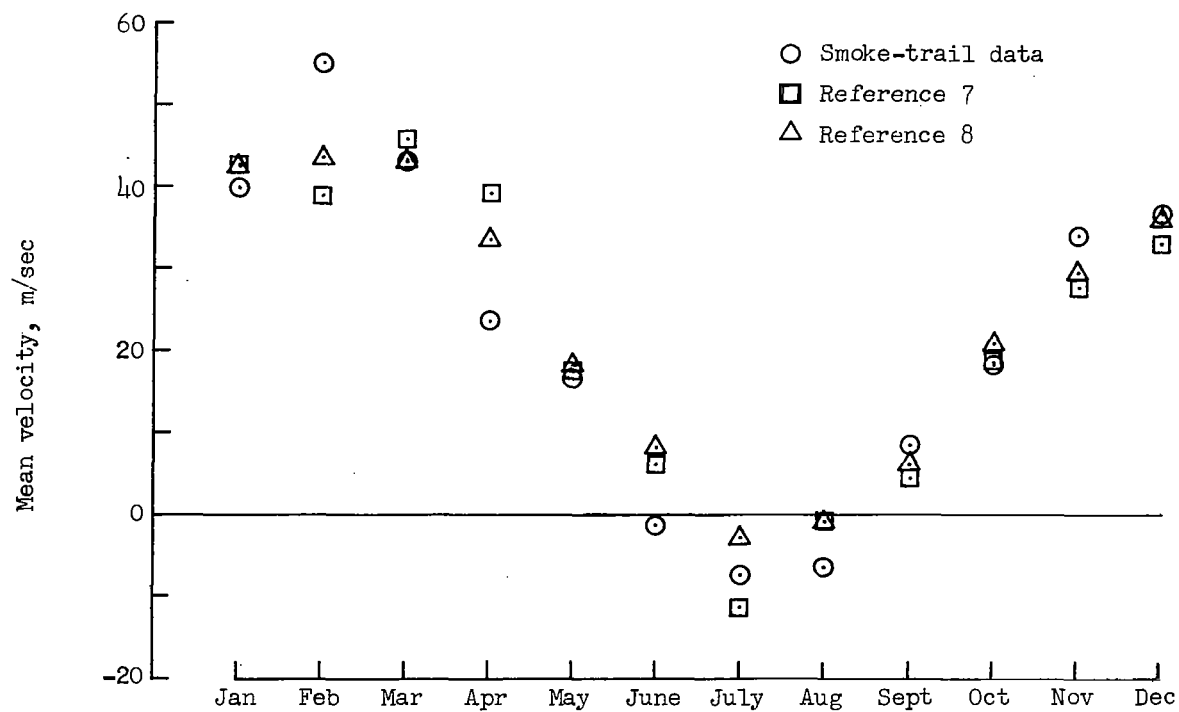


Figure 32.- Mean wind velocity of the zonal component measured at an altitude of 13 km at the Eastern Test Range.

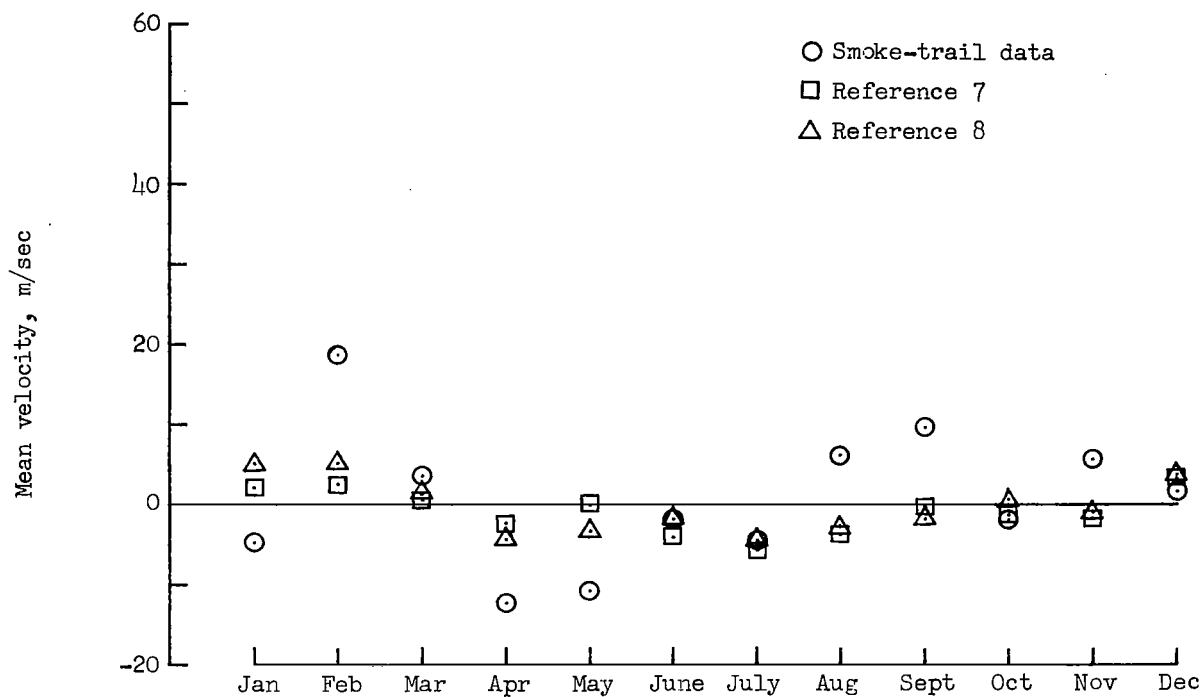


Figure 33.- Mean wind velocity of the meridional component measured at an altitude of 13 km at the Eastern Test Range.